Design Process Components and Perceived Product Quality

ISBN: 978-90-9030-019-1
NUR-code: 656
Cover design: Barbara N. E. Kok
Illustrations Sebastiaan I. D. Kok

Design Process Components and Perceived Product Quality

Can a Design Education Program Contribute to better Product Quality?

Proefschrift

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus prof.ir. K.C.A.M. Luyben,
voorzitter van het College voor Promoties,
in het openbaar te verdedigen op
4 november 2016 om 12:30 uur

door

Barbara Nettie Elisabeth KOK
Licentiaat in de Medisch Sociale Wetenschappen, Vrije Universiteit Brussel
geboren te Bree, België

Dit proefschrift is goedgekeurd door de
Promotor : Prof. dr. P. Vink
Copromotor: dr. K. Slegers

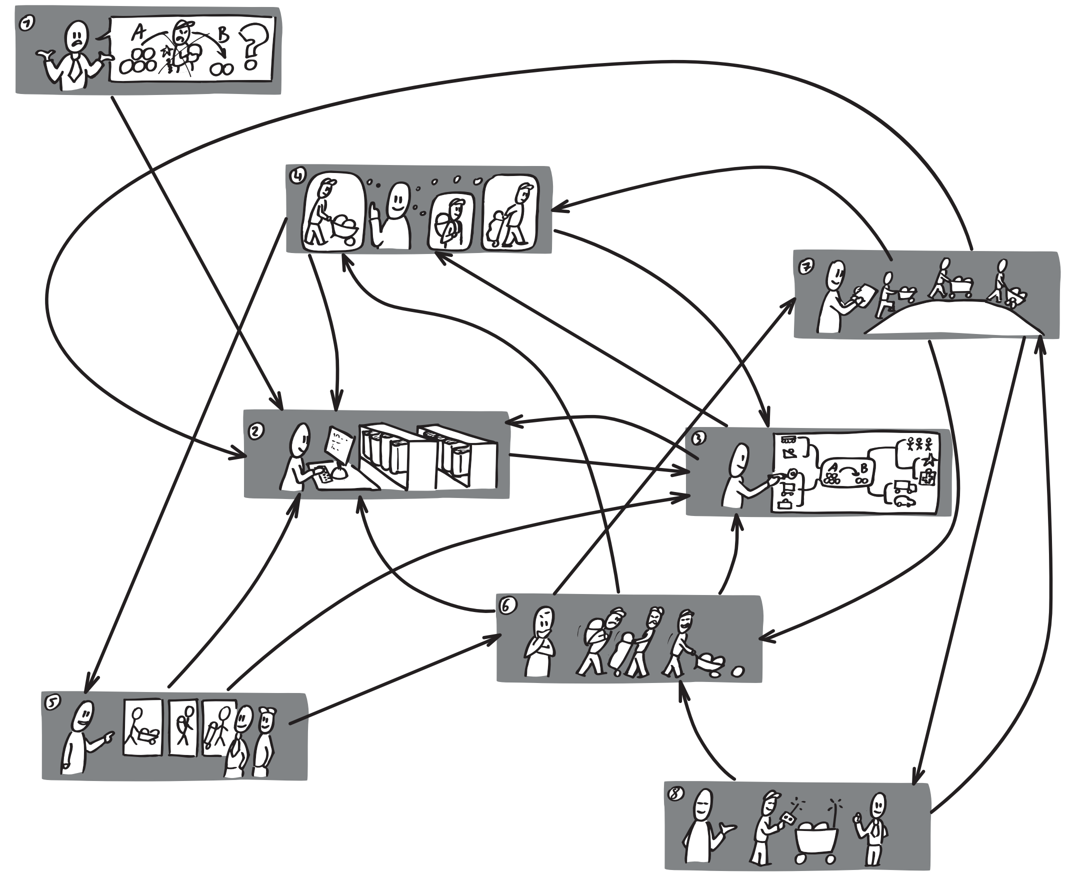
Samenstelling van de promotie commissie:

Rector Magnificus	Voorzitter
Prof. dr. P. Vink	Technische Universiteit Delft, promotor
Dr. K. Slegers	Katholieke Universiteit Leuven, copromotor
Onafhankelijke leden:	
Prof. dr. A.S. Nyssen	University of Liège, Belgium
Prof. dr. P.J. Stappers	Technische Universiteit Delft
Prof. dr. P.G. Badke-Schaub	Technische Universiteit Delft
Prof. dr. M.S. Hallbeck	University of Nebraska–Lincoln, USA
Dr. K. Keignaert	Universiteit Antwerpen, Belgium

Ter nagedachtenis van
Alexander Frank Philip Kok

— *"My spelling is Wobbly. It's good spelling but it Wobbles, and the letters get in the wrong places."*

— Winnie the Pooh, 1924.



DESIGN
PROCESS
COMPONENTS
AND PERCEIVED
PRODUCT QUALITY

Table of Contents

Abbreviations

DP	Design process
DRT	Design research tools
FTA	product function & task analysis
FTA & RMA	product risk, mistake function and task analysis
FT-RM-ST	product risk, mistake function & task analysis by self-testing
OEM	Original Equipment Manufacturers
PPQ	perceived product quality
RMA	product risk & mistake analysis
SPSS	Statistical Package for the Social Sciences
TF-RM-DP	product risk, mistake function and task analysis designed product

Preface

As an ergonomist and as a teacher in design I am obviously very interested in the user experience of product and more specifically in how this user experience can be altered through design. I often wondered why products are sometimes experienced as bad or not good enough by end-users and what education can do about this. This was an interesting topic to start a PhD and I am grateful that my employer enabled me to start a PhD on this topic. This PhD thesis is composed of nine Chapters. Seven of these Chapters are papers that are published in International Journals, chapter of a book, or in conference proceedings. These papers are integrated into the PhD thesis and some of the information found in several Chapters is repeated. The integration of the full papers allows the reader to examine Chapter 2 through 8 separately. Chapter 1 is the introduction. Chapter 2 through Chapter 8 are separate studies and the relationship between these chapters and presented studies are the basis for this PhD thesis. Chapter 9, is the final chapter and is a global reflection on which this PhD thesis is founded.

CHAPTER 1

Introduction

Design Process Components and Perceived Product Quality

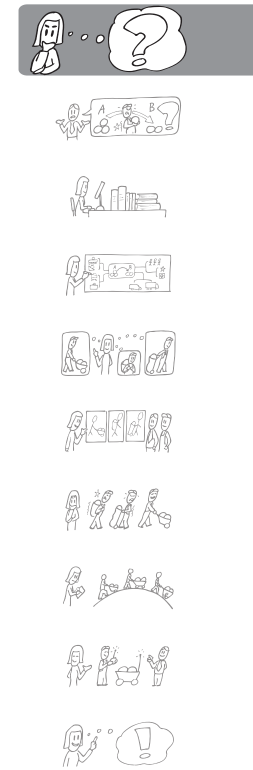
1 INTRODUCTION

1.1 PRODUCT DESIGN IS CHANGING

Today people use and rely on a memory stick or computer tablet, products they never imagined existed 20 years ago. Additionally, as products change, the behaviours and expectations of people change. One example of an activity that has changed during the last century is making coffee. Coffee beans used to be ground at home and hot water was poured over the ground coffee. Nowadays, many people make coffee by putting a capsule into a machine. Additionally, the product market is no longer limited to tangible products but includes virtual products, such as videogames, and services. An example of a service is performed by airline services: which is more than an airline ticket and a seat on a plane. In order to get on the right plane at the right time a whole system was designed and the ticket is a means to help the customer through the procedures and to find her/his seat on the plane.

The needs, wishes and expectations of customers and users in general also change. The amount of money spent on products has increased exponentially in the last century (Scholliers, 2014), suggesting people like to own more stuff. However according to Dijck (2007) another trend is seen as well: people value attachment, meaning and experience over the quantity or number of products. This group of people no longer want more products, but better products (Dijck, 2007). Identifying and understanding what people need and expect from products is not an exact science. In fact, user expectations vary over time (Vink, 2014) and are influenced by many factors (Tiemeijer et al., 2009; Schifferstein and Hekkert, 2008; Vink and Hallbeck, 2012). When it comes to making product choices, decisions are influenced by users' previous experiences of similar products and their knowledge as well as emotions, habits, perceptions and social and physical environments (Tiemeijer et al., 2009).

Historically one of the priorities of design is to analyse the cultural and social context in order to create progression in the form of everyday experience (Beirne, 2011). Product designers can contribute to good experiences by creating a good perceived quality product. In order to create a good perceived quality product, designers need to anticipate users' needs, wishes, and expectations, which are each uniquely influenced by the constantly changing society and technological progress. Additionally, designers need to be able to predict future trends and create designs that match future expectations (Rijk, 2014). Good perceived product quality can, amongst others, be achieved by conducting usability studies (e.g. Dumas, 2007), by applying principles from human factors and ergonomics (e.g. Dul et al., 2012; Lee, 2006), by following a participatory design approach (e.g. Luck, 2003) or a human-centred design approach (Vink et al. 2008) in the design process. Given this large array of resources for designers, one might expect a large number of good quality products that meet the users' needs. However, such needs, wishes and expectations are still often not fulfilled (Norman, 2010, Den Ouden, 2006; Nielsen, J. 2012; Van Kuijk, 2009).



These changes in product experiences, product use, and the need for a more human-centred design have consequences for teaching the design processes, which is the topic of this PhD thesis. In the following paragraphs, product quality and the design process will be explored (paragraph 1.2). The link between the design process and product quality is in the product characteristics (see fig 1.1). This link will be described in paragraph 1.3 and an important part of the link design education and product experience is also described in paragraph 1.3 followed by the field (education) wherein the research was performed and the central research question.

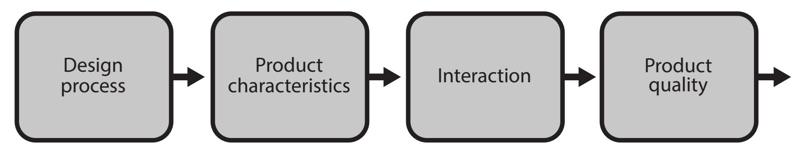


FIGURE 1.1: *the link between the design process and product quality determining the paragraphs in this chapter from left to right.*

There are many type of products: tangible virtual, services etc. This research focusses on tangible functional products, because the different types of products create different kinds of experiences, for example a virtual product (such as a website) does not have a weight etc. Additionally users may have different needs, wishes and expectations towards each of these type of products. Consequently, the design process can be different. For example, a designer does not have to take into account the possible weight of the product when designing a virtual product such as a website. These differences in design approaches make comparisons between these design processes difficult therefore the focus of this research is narrowed to tangible products.

1.2 PRODUCT QUALITY AND THE DESIGN PROCESS

1.2.1 PERCEIVED PRODUCT QUALITY

In research literature, perceived product quality is defined as the consumer's judgment about a product's overall excellence or superiority (e.g. Tsiotsou, 2006; Bei and Chiao, 2001; Zeithaml, 1988). The perceived product quality can be different from the objective product quality (Tsiotsou, 2006; Bei and Chiao, 2001; Zeithaml, 1988). According to Aaker (1991) the perceived quality is different from actual or objective quality, product-based quality, and manufacturing quality. Bhuian (1997) distinguishes extrinsic and intrinsic contributions to the perceived product quality. The extrinsic quality lays outside the product. Watching others using it is an example of extrinsic quality. This intrinsic quality is attributes that cannot be changed without changing the physical characteristics of the product itself. It is this intrinsic quality that is the focus of the research described in this PhD thesis as it can be influenced by the product design process. In this PhD thesis, perceived product quality focuses specifically on the functionality and usability, design (aesthetics, shape, colour, texture, etc.) and maintenance. The functionality, usability and maintenance of a product affect the efficiency of product use. Therefore, these aspects are a part of the perceived product quality studied. The design (aesthetics, shape, colour, texture, etc.) is included because as shown in the study by Sonderegger and Sauer (2010) the appearance of a product (phones in their study) can have a positive effect on performance, leading to reduced task completion times for the more attractive models.

The way products are used and experienced nowadays influences the perceived product quality. The user experience and its relation with the design process is further described in 1.2.3. Hekkert and Schifferstein (2008) define the field of experience design as "the research area that develops an understanding of people's subjective experiences that result from interacting with products". They state that product experience results from the interaction the user has with a product. Kuijk (2009) states in his PhD thesis about the usability of electronic consumer products that the product experience often occurs before using the product, e.g. when observing others using the product. According to Kuijk et al. (2009) the product use varies in different phases of the product (see Figure 1.2). His model shows the different ways in which a product can be experienced. These experiences can also occur before and even after abandoning the product.

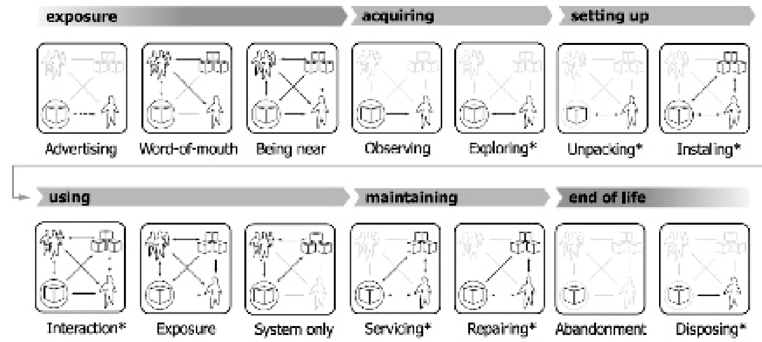


FIGURE 1.2: *The product usage cycle: an illustration of how human-product interaction can vary per phase (Kuijk, 2009).*

The product experience is influenced by the product's characteristics (Vink and Hallbeck, 2012). Based on the definitions of these studies (Kuijk, 2009; Hekkert and Schifferstein, 2008; Vink and Hallbeck, 2012), the product experience defined in this PhD thesis is: *people's subjective experiences that result from interacting with products, and are influenced by the product characteristics and that often already commence before (or without) using the product.*

Definitions used in this PhD research

Perceived product quality: People's subjective experiences of the functionality, usability, maintenance, and design of a product. (bases for the discussion above.)

Functionality: the set of functions or capabilities associated with a product, whether it provides the features needed. (Based on Merriam –Webster Dictionary and Nielsen, 2012)

Usability: is a quality attribute that assesses how easy the product's usability is defined by three quality components:
- Learn ability: How easy is it for users to accomplish basic tasks the first time they encounter the design?
- Efficiency: Once users have learned the design, how quickly can they perform tasks?
- Errors: How many occur, how severe are these errors, and how easily can they recover from the errors? (Nielsen, 2012)

1.2.2 DESIGN PROCESS

Holston (2001) states that, *"The design process offers an inclusive approach for arriving at innovative design ideas that can differentiate the client (= company) from their competition and connect at a deeper level with audiences."* He also states that the design process, *"helps the designer to stay focused, …to manage the complexity of projects by providing a system for organizing information and people, …and provides a framework for collaboration…"*. The design process has many functions and is discussed much in the literature (Holston, 2001). This PhD thesis studies relationships between the design process and the perceived product quality. The focus in this research is on only a part of the design process. The perceived product quality, especially the intrinsic quality, is influenced by the product characteristics. These product characteristics are influenced by a number of things i.e., the actions, steps, methods, tools, etc. chosen and used by the designer in the design process. This PhD thesis these will refer to design process components actions as, steps, methods, tools, etc. There is a considerable body of literature on design processes e.g., The Delft Design Guide by Boeijen et al.,(2013) and Research Design: Qualitative, Quantitative and Mixed Methods Approaches by Creswell (2003). According to Boeijen et al. (2013) there are many ways to realize a design and they state that the more methods the designer uses, in the early phases of the design process, the better the designer can approach design problems effectively and efficiently. Wynn and Clarkson (2005) distinguish three ways of approaching design processes: the abstract, analytical and procedural approach. The first approach: the abstract approaches, which is used to describe the design process at a high level of abstraction, can be applied to many processes. This approach is relevant for a broad range of situations, but does not offer specific guidance useful for process improvement (Wynn and Clarkson, 2005). The abstract approach was not used because in this research the design processes are studied in order to be able to formulate recommendations to improve the design process. The analytical approach, is used to describe particular instances of design projects. In this PhD thesis research the analytical approach was not used, since it is a more detailed approach which is generally used to analyse the effect of, for example, the product architecture or material or the information flow between the different actors in the design process (Wynn and Clarkson, 2005). The focus of this PhD research is on how the design process can affect the product quality. The focus is on the complete design process, not on a specific part of the design process.
The approach used in this research is the procedural approach, because the whole design process of concrete design projects is studied. In the procedural approach the design process is studied in a descriptive way by studying actual processes, or prescriptive way, by formulating recommendations based on the studies (Wynn and Clarkson, 2005).
According to Buijs and Valkenburg (2005) and Roozenburg and Eekels (1995) the design process starts with product policy and ends with production, sales, and product use. This PhD focusses on the Basic Design Cycle of Roozenburg and Eekels (1995), including analysis, design criteria, synthesis, provisional design, simulation, expected properties and evaluation, the designer has most concrete influence on this part of the design process. Policy and production and sales are excluded.

1.2.3 DESIGN PROCESS COMPONENTS AND PERCEIVED PRODUCT QUALITY

There is a considerable body of literature on design processes i.e., the already mentioned 'Delft Design Guide' by Boeijen et al.(2013) and 'Research Design: Qualitative, Quantitative and Mixed Methods Approaches' by Creswell (2003) presents many design methods, highlighting several components that are clear examples of design process descriptions. However, literature about the influence of the individual design process components on the perceived quality of the designed product is sparse.
Studies about design processes often address a specific design phase, (i.e., Gonçalves et al. 2014; Bender and Blessing, 2004), a specific design problem (i.e., Daalhuizen, 2014), a specific product (i.e. Opsvik, 2008), or a specific design method (i.e., Kujala, 2003). For example, Opsvik's (2008) study of different design approaches resulted in totally new sitting products which sometimes were completely different from classic chairs. Other studies concern specific materials in the design process i.e., the study of Byars (1998) about innovation in design and materials, which focussed on the use of materials and how materials affect the design. Many studies have focused on a specific method or methodologies in design and how these methods or methodologies improve the design (Clevenger et al., 2013; Lobos and Babbitt, 2013; Denny et al., 2011; and Bargelis et al. , 2014). Other research focussed on designers' attitudes and how these affect design and designed products (for example Denny et al., 2011 and Rijn et al. 2011). This PhD research will analyse which design process components can affect the user experience of products. The whole design process was studied and there was no focus on one specific type of product.
In the literature several models of perceived product quality are available. For example, Bei and Chiao (2001) created a model that explains the effect of (perceived) product quality. Their study focussed on the effect of the (perceived) service quality and (perceived) price fairness on consumer satisfaction and consumer loyalty. Their study showed that consumers establish higher loyalty towards a service when they are more satisfied with the service. Tsiotsou (2006) created a model to explain the role of perceived product quality and overall satisfaction on purchase intentions. This study showed that overall satisfaction, product involvement and purchase intentions are down when there is a low perceived product quality. Product involvement and purchase intentions are up when there is a high perceived product quality. These models however do not show how the design process affects the perceived product quality. The product quality is a result of how the users experience the product. Vink and Hallbeck (2012) created a model which showed the

relationship between a product's characteristics and the user's perception of (dis)comfort of the product (see figure 1.2). In this model the interaction (I), between user and product results in internal human body effects (H), such as tactile sensations, body posture change and muscle activation. The perceived effects (P) are influenced by the human body effects, but also by expectations (E). These are interpreted as comfortable (C) dis-comfortable (D) or neither comfortable nor dis-comfortable. Over time this discomfort could lead to musculoskeletal complaints (M).

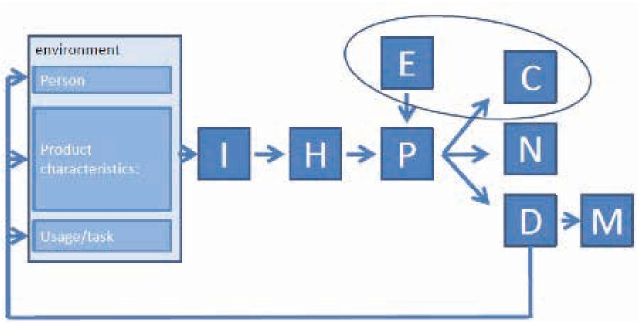


FIGURE 1.3: *The comfort model of Vink and Hallbeck (2012)*

In order to visualise the relationship between the design process and the perceived product quality, a new model was created. This PhD thesis adapted and broadened the model of Vink and Hallbeck (2012): the new model focusses on perceived product quality. This model assumed that many factors may affect perceived product quality (Schifferstein and Hekkert, 2008), such as the user's emotions or the task use of the product (e.g. a screw driver can be used to screw in a screw to wood but may also be used to open a can of paint).
The adapted version of Vink and Hallbeck's model, the Product Design – Quality – Model, used in the research and described in this PhD thesis is presented in Figure 1.3. In this adapted model, the perceived quality of a product is affected by several factors. One of the factors is formed by the product characteristics. The product characteristics result from the components applied during the design process. Product quality is experienced when the product is used or perceived, e.g. seeing the product while observing someone using it or using it by oneself. This interaction with the product can have a physical, sensory, cognitive and emotional effect on the user. The perception of these effects is influenced by several factors such as previous experiences, the user's expectations, preferences, emotions, etc. This perception is processed in the brain and results, amongst others, in an perception about the product quality. Additionally, the perception can also influence the interaction by adapting the usage.
Of all these factors, designers can influence the 'product characteristics' the most because these are a direct result of the steps and choices made by the designer with tools and methods used during the design process or what is referred to in this PhD thesis as the 'components of the design process'.

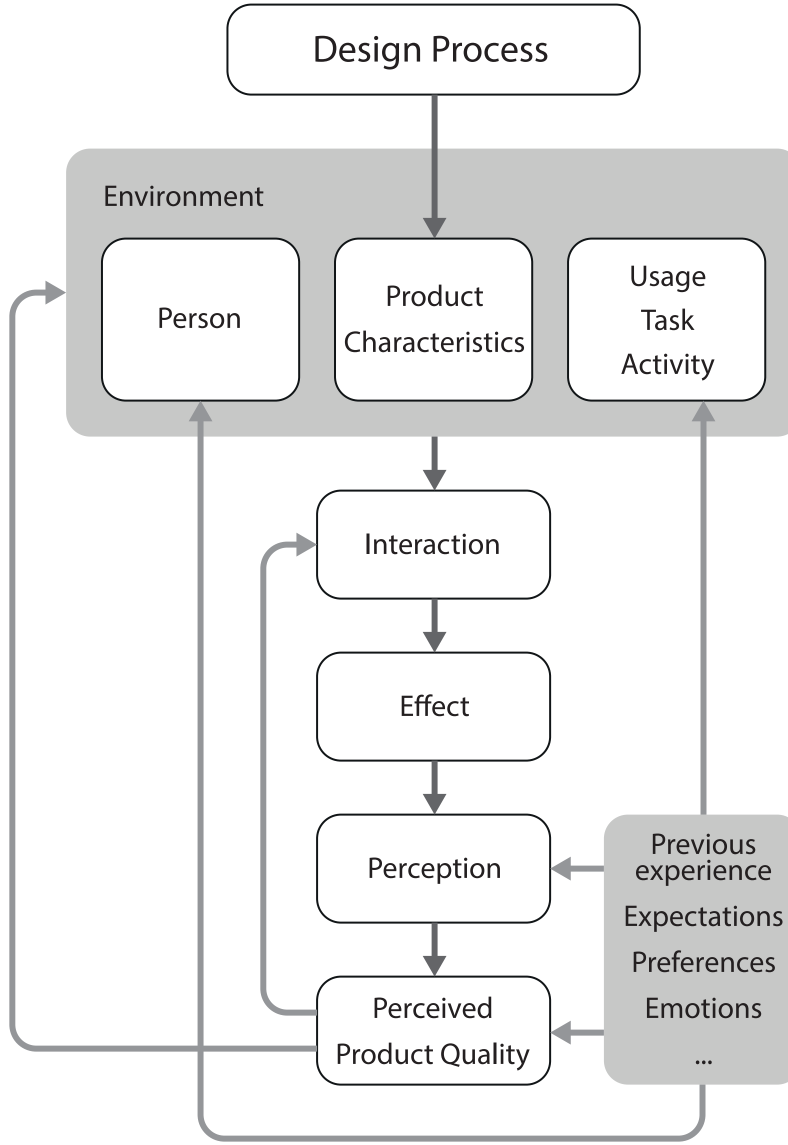
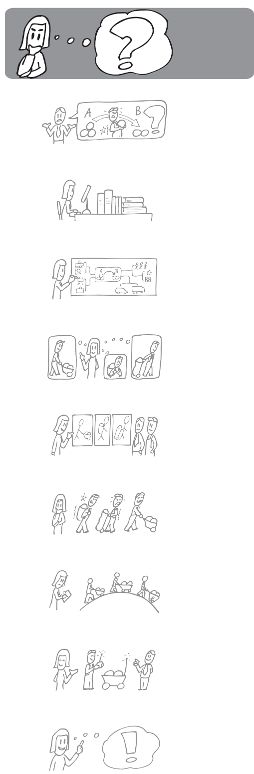


FIGURE 1.3: The product – design – quality – model inspired by the comfort model of Vink and Hallbeck (2012).



1.3 PERCEIVED PRODUCT QUALITY AND PRODUCT DESIGN EDUCATION

The choice of the components that are applied in the design process depends on the strategy of the designer. If designers are aware of the design process components that have a positive effect on the perceived product quality, they could implement the components (more) into their design process. This awareness could be achieved by publishing papers about the effect of the design process components on the perceived product quality in scientific and academic journals. However, Evans (2015) stated academic papers don’t reach the designers, so they do not get information from academic journals. Another way to reach (future) designers is through design education. The purpose of design education is to prepare future designers with the skills and attitudes needed to develop products that create progress in the form of everyday experiences (Oxman, 2004). During the formal education programs future designers acquire skills and develop perspectives that are important in the design process. Education can stimulate the creation of good products by designing a curriculum by which future designers can acquire qualitative competences and learn to use methods, tools and skills which can have a positive effect on product quality.

In this PhD thesis research is done to analyse the relationship between individual components of the design process applied by students and the perceived product quality. There are many different design institutes, all of which have their own vision on design of which result in varying curricula. The following describes design education and product design education in Flanders. The Danish Design Manifesto (2010) states that a design vision is for “people, profit and planet”, which is in the design vision of many educational institutions. However, there are differences amongst them. In Flanders, Belgium, for instance, there are three institutes providing a Master‘s education program in product/industrial design/development: the Master program in Industrial Design at the University of Ghent, the Master program in Product Development at the University of Antwerp and the Master program in Product Design at the LUCA School of Arts, C-mine, Genk. The curriculum of technology, economy and research are common aspects of these programs (VLHORA, 2010a; VLHORA, 2010b; VLHORA, 2012). The differences with the three programs are found in the approach to design. At the University of Ghent, the Industrial Design Education is part of the Industrial Science department and the focus of the education program is on technology and design (VLHORA, 2010b). The University of Antwerp’s Product Development Education is situated between the industrial approach, the business-like approach, and the artistic approach of design (VLHORA, 2010a); the program focusses on the industrial, the economic as well as the human-centred aspects of design engineering. For this reason, the educational program of the University of Antwerp identifies itself as an integral product development program. At the LUCA School of Arts, C-mine, Genk, the Product Design program focusses on the artistic, social and human-centred aspect of design (VLHORA, 2012). These differences of vision on design reflect the different design educational programs, result in different courses. The Master program in Product Design (LUCA School of Arts, C-mine, Genk) has many more art science courses embedded in the curriculum than the other two institutes. The majority of data used for this PhD research were collected in the Product Design Education department at the LUCA School of Arts, C-Mine, Genk.

1.4 PRODUCT DESIGN AT THE LUCA SCHOOL OF ARTS

In order to ensure validity of results, a comparison was made between the design processes of the designer students at the LUCA School of Arts (C-mine, Genk) and professional designers.

The Product Design Education of Genk (LUCA School of Arts, C-mine, Genk,Flanders, Belgium) focuses on the art orientation of education. This program started in 1969, at the City Higher Institute for Visual Communication and Design. The City Higher Institute for Visual Communication and Design was integrated into the Catholic University College of Limburg in 1994 as the Media and Design Academy. In 2012, the Art department of the Provincial University College (PXL, Hasselt) and Media and Design Academy (KHLim, Genk) were united in the Media, Art and Design Faculty (MAD-fac) with two campuses; one in the city of Hasselt (Free Arts) and the other in Genk (Applied Arts). Recently, in 2015, the Genk-based Mad-fac campus was integrated into the LUCA School of Arts.

Students are trained in art, technology, social science, human science, technology, economy and research in the Product Design curriculum of the LUCA School of Arts, (VHLORA, 2012). The students are trained in the skills and knowledge to create products in answer to socially relevant problems. Students are trained to create (design) answers to problems based on contextual research and focus on the social situation in which the problem occurs. The design answer will often be a product but can also be a service or system. Other Flanders’ product/industrial design education is industrial in nature and more focussed on professional practice, than art. The product design education focusses more on the user and the social relevance more than the demands of the industry.

1.5 RESEARCH DESIGN

1.5.1 RESEARCH FOCUS

The original research topic was to study design processes of mainly professionals; and the effect of perceived product quality, because products are primarily designed by professionals. Therefore, studying the design processes of products which are already on the market allows researchers to measure the effect of the design processes on the perceived product quality throughout the products lifecycle. The perceived quality can differ after frequent use from the perceived quality in the beginning. However it is difficult to obtain information concerning the design processes of professional designers, as they often do not want to share their unique approaches and many have limited time for additional research. Therefore, the data gathered for this research is limited to primarily student designers. Differences between the design processes of professionals and design students can be expected because of different contexts in which they work, and work experience. Gonçalves et al. (2014) showed the differences in the design approach of professionals and design students. They compared the sources for ideas inspiration of students to the sources of professionals. Their study showed that professionals utilize ergonomic and functional study more often as a source of inspiration then students. Professionals tend to use more prototyping and scenarios to generate ideas than student designers. This research is based on the design processes of students additionally of a comparisson the design processes of design students with the design processes of professionals was done."

This research focusses on tangible functional products only, as mentioned in 1.1. Within the tangible products there are functional and art products for which the design approaches may differ. For art products such as jewellery or paintings, the emotional and aesthetic aspects are of more importance than the functional aspects. Therefore, it is difficult to compare the design processes of functional and art products. Because of this difficulty the art products were excluded from this research. As mentioned in paragraph 1.5, the focus of this PhD research is on the intrinsic characteristics: the functionality and usability (ease of use, adjustability, the extent to which expectations concerning this product are fulfilled), the design (colour, shape texture etc.) and ease of maintenance.

Based on this PhD research, recommendations towards design education will be formulated. Design education can affect the design processes of students by the design methods, tools etc. taught in the Institutes. Designers tend to apply design process components with which they are familiar more than other design process components (Baber and Mirza, 1988; Stanton and Young, 1998). Design students are probably more likely to apply design process components which they presume to result in better grades, which could influence the outcome of this research. Therefore it is interesting to study the ability of design teachers to estimate the users experience, because design students are mainly assessed by teachers. This ability of teachers to estimate the users experience is studied in this PhD research.

1.5.2 RESEARCH GOAL AND QUESTIONS

The main goal of this PhD thesis research was to study which design process components can contribute to a better perceived product quality.
In order to answer this question the following strategy was applied: The first step in achieving this goal is to identify which components are applied in the actual design processes by students. Secondly, the relationship between these identified components and perceived product quality is investigated. To validate the results, which are based on data from design students' design processes, a comparison between the design processes of professionals and of students is made. Additionally, the ability of teachers to estimate the users' perception of product quality is studied.
The main research question of this PhD thesis is:

Which design process components contribute to a better perceived product quality?
The sub-questions are:

1) *Which components can be distinguished in the design process?*
2) *How do individual design process components relate to the perceived product quality?*
3) *Are there differences in the design process of design students and professional designers?*
4) *Are design teachers able to estimate the end users' product experience?*

1.5.3 RESEARCH STRUCTURE

The PhD thesis consists of three parts. In the first part, the components of the design process that are relevant for the product quality are identified, described and categorized. This was essential to develop a clear view of the components that are applied by designers in the design process. In addition, the effects of students experience in certain fields (such as ergonomic studies or user involvement) were studied on the actual application of components related to these fields (for example applying ergonomic and functional study or having users involved in the design process). In the second part of this PhD thesis the relations between the application of the design process components and the perceived quality of the final product are studied. In the final part, the capability of design teachers to estimate users' perceived product quality was studied and a comparison of the design processes of student designers and professionals was conducted. Table 1.1 shows an overview of the PhD structure.

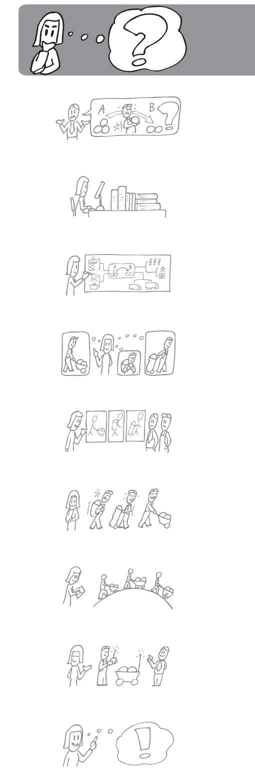


Table 1.1 An overview of the thesis structure and papers

CHAPTER	TITLE	ARTICLE	PUBLISHED IN
I. COMPONENTS IN THE DESIGN PROCESS			
2	Components in the design process	Conference paper: Published title: Methods of the design process: an inventory.	ODAM conference, Grahamstown, SA, 2011 Work 41: 989-996
3	Does the experience in ergonomics and design research tools influence the application of components in the design process?	International Journal paper: Publishing title: The amount of ergonomics and user involvement in 151 design processes	Internation Journal WORK, A Journal of Prevention, Assessment & Rehabilitation, 41, pp. 989-996, 2011
II. THE EFFECT OF THE COMPONENTS IN THE DESIGN			
4	The effect of the designer's approach on the perceived product quality of tangible products: an exploratory case study	Conference paper: Publishing title: The effect of the designer's approach on the perceived product quality: an exploratory case study of tangible products.	European Academy of Design conference Paris 2015: The Value of design research
5	The effect of the designer's approach on the perceived product quality: an exploratory case study of tangible products	Conference paper: Publishing title: Components in the design process essential for ergonomic sound products. Submitted 2015.	International Journal of Ergonomics in design
6	Essentials in the design process for creating comfort in seating products for vehicles	International journal paper: Publishing title: Essentials in the Design Process for Creating Comfort in vehicle Seats. Accepted February 2016.	International Journal of Applied Ergonomics.
III. DESIGN EDUCATION VERSUS THE REAL WORLD			
7	Can Teachers estimate the users' product quality perception	Book chapter: Can design teachers evaluate students' products from an end-user point-of-view?	Advances in Social and Organizational Factors 2014, Ed. P Vink, Published by AHFE Conference © 2014, page 59-67.
8	Are Seat Design Processes of Students Similar to those of Professionals?	International journal paper: Publishing title: Are seat design processes of students similar to those of professionals?	WORK, A Journal of Prevention, Assessment & Rehabilitation

References

BABER, C. AND MIRZA, M.G., (1988), Ergonomics and the evaluation of consumer products: surveys of evaluation practices, in *Human Factors in Consumer Product Design*, Stanton, N.A., Ed., Taylor & Francis, London.

BATTARBEE, K. AND MATTELMÄKI, T., (2002), Meaningful Product Relationships, *Design and Emotion conference*, 1-3 July 2002 Loughborough, England.

BARGELIS, A., CIKOTIENĖ D. AND RAMONAS, Z., (2014). Impact of human factors and errors for product quality and reliability in the integrated approach of product and process design, maintenance and production. *IJ Mechanika*, Volume 20(1): 92-98.

BEI, L.T. AND CHIAO Y-C., (2001), an integrated model for the effect of perceived product perceived service quality, and perceived price fairness on consumer satisfaction and loyalty. Journal of consumer Satisfaction, Dissatisfaction and Complaining Behaviour, Vol 14: 125- 140.

BEIRNE, P. (2011), From Object to Objective: Reframing the Goals of Product Design Education in a Postindustrial Context. *IJ Design Principles and Practices*, Vol.5, Issue 6, ISSN 1833-1874.

BENDER, B., AND BLESSING, L. (2004), On the superiority of opportunistic design strategies during early embodiment design. *8th International Design Conference*, Dubrovnik, Croatia, 117-122.

BEVAN, N., (1999), Quality in Use: Meeting User Needs for Quality. *Journal of System and Software.*

BHUIAN, S. N. (1997), Marketing cues and perceived quality: Perceptions of Saudi consumers toward products of the U.S., Japan, Germany, Italy, U.K., and France. Journal of Quality Management, vol. 2 (2), pp. 217-235.

BOEIJEN, A., VAN, (RED.), DAALHUIZEN , J, (RED) ET AL., (2013), *Delfts Design Guide*, TU Delft, NL.

BUIJS, J. AND VALKENBURG, R. (2005), *"Integrale Productontwikkeling".* (integral product development),Utrecht, Lemma, NL.

BYARS, M. (1998). *50 Products: Innovations in Design and materials.* Crans-Près-Céligny RotoVision.

CLEVENGER, C. M., HAYMAKER, J. R. AND EHRICH, A. (2013), Design exploration assessment methodology: testing the guidance of design processes. *IJ Engineering Design*, Vol. 24, No. 3, 165–184.

CRESWELL, J.W, (2003), *Research Design: Qualitative, Quantitative and Mixed Methods Approaches.* SAGE Publications, London.

DAALHUIZEN, J.J., (2014), *Method Usage in Design: How methods function as mental tools for designers*, PhD thesis, chapter 3,pp. 63-96, TU Delft, NL.

DENNY, K.-L. H., MA, J. AND LEE, Y. (2011), Empathy @ design research: a phenomenological study on young people experiencing participatory design for social inclusion. *IJ CoDesign*, Vol. 7(2),June 2011, 95–106.

DIJCK, F., VAN , (2007). *Het merk mens: Consumenten grijpen de macht. (the brand human: consumers seize power)* . Terra – Lannoo, BE.

EVANS, M., (2015), Designers don't do journals: case studies in the development of research-based resources to support design practice and education. *The value of Design Research. European conference of design conference*, Paris, France.

FORLIZZI, J. AND BATTARBEE, K., (2004), Understanding experience in interactive systems. *2004 conference on Designing interactive systems: processes, practices, methods, and techniques*, Vienna, ACM Press, AT.

FORLIZZI, J., AND FORD, S., (2000), Building blocks of experience: An early framework for interaction designers. In *DIS 2000 Designing Interactive Systems Conference* (ACM), pp. 419 - 423.

GONÇALVES, M., CARDOSO, C., AND BADKE-SCHAUB,P., (2014), What inspires designers? Preferences on inspirational approaches during idea generation. *Design Studies Vol. 3*, pp 29-53, http://dx.doi.org/10.1016/j.destud.2013.09.001.

HEKKERT, P. AND DESMET, P., (2007) "Framework of Product Experience. *International Journal of Design* (1): 57-66.
HOLSTON, D. (2001): The strategic designer. Tools and techniques for managing the design process. HOW Books. F+W Media. Ohio, USA.

KOK, B. N., SLEGERS, K., AND VINK, P. (2011). Methods of the design process: an inventory. *Human Factors in Organisational Design and Management - X* (pp. 275-280). ODAM, Grahamstown, SA.

KUIJK, J.I. VAN , (2009) Managing product Usability: How companies deal with usability in the development of electronic consumer products. PhD Thesis, TU delft, faculty of industrial design engineering, NL.

KUIJK, J.I., VAN, PREIJDE, E.E. , TOET, E.N., AND KANIS, H., (2009), Expected versus experienced usability: what you see is not always what you get. IEA 2009: the 17th world congress on ergonomics, August 9-14 2009, Beijing, China.

KUJALA, S., (2003), User involvement: A review of the benefits and challenges, *Behaviour & Information Technology*, Vol. 22, 1, pp. 1-16.

LEARNERS DICTIONARY retrieved may 2011, from: http://www.learnersdictionary.com/definition/design.

LOBOS, A., AND BABBITT, C. W. (2013). Integrating Emotional Attachment and Sustainability inIntegrating Emotional Attachment and Sustainability in Electronic Product Design. *IJ Challenges, vol 4*, 19-33; doi:10.3390/challe4010019.

MERIAM –WEBSTER DICTIONARY, retrieved may 2011, from: http://www.merriam-webster.com/dictionary.

NIELSEN, J. (2012), *Usability 101: Introduction to Usability.* retrieved from: www.nngroup.com/articles/usability-101-introduction-to-usability/, posted January 4, 2012

NORMAN, D. (2010), *The Research-Practice Gap, Essays, retrieved dec 5, 2010, from.* retreived, March 2015 Don Norman: Design for People: http://www.jnd.org/dn.mss/the_research-practice_gap_1.html

OPSVIK, P. (2008). *Rethinking Sitting.* Oslo, Norway: Gaidaros Forlag SA.

OXMAN, R. (2004). Think-maps: teaching design thinking in design education. *IJ Design Studies 25, 63–91*, Vol 25, 63–91.

ROOZENBURG, N. AND EEKELS, J. (1995) Product Design: Fundamentals and Methods, Chichester: Wiley, 1995, pp. 53-81

RIJK, DE, T. (2014). *Inaugural: What design can do!* Retrieved from TU Delft recordings inaugural,{podcast}: http://www.io.tudelft.nl/en/news/congresses-and-symposia/recordings-inaugural-address-timo-de-rijk/

RIJN, VAN, H., SLEESWIJK VISSER, F., STAPPERS, P. J., & ÖZAKAR, A. D. (2011), Achiving empathy with users:the effects of different souorces of information. *IJ CoDesign*, Vol. 7, No. 2, June 2011, 65–77.

SCHOLLIERS, P., (2014), *Historische vraagstukken Hedendaagse Periode 1.* VUB, http://www.vub.ac.be/SGES/SCHOLLIERS1.html

SCHIFFERSTEIN , H. N., AND HEKKERT, P. (2008), *Product experience.* Amsterdam: Elsevier Science,NL.

SONDEREGGER A. AND SAUER J., (2010), The influence of design aesthetics in usability testing: Effects on user performance and perceived usability., May 2010, Pages 403–410.

STANTON, N.A. AND YOUNG, M. (1998), Is utility in the mind of the beholder? A review of ergonomics methods, *Appl. Ergonomics*, vol. 29, 41–54.

TIEMEIJER, W.L.; THOMAS, C.A. AND PRAST, H.M. (2009), *De menselijke beslisser. (the Human decission maker)*, Amsterdam University Press, NL.

TSIOTSOU, R. (2006), The role of perceived product quality and overall satisfaction on purchase intentions. *International Journal of Consumer Studies.*Vol 30, Issue 2, pp 207–217.

VINK, P. (2014). *The Sweetness of discomfort: Designing the journey. in augural address.* TU Delft, NL.

VINK, P., & HALLBECK, S. (2012). Editorioal: Comfort and discomfort studies demonstrate the need for a new model. *IJ Applied ergonomics*, Vol 43, 271-276. Doi: 10.1016/j.apergo.2011.06.001.

VLHORA, 2010a, *Onderwijsvisitatie productontwikkeling. (Education audit: product development)*, 4 Mars 2010, BE.

VLHORA, 2010b, *Onderwijsvisitatie Industriële wetenschappen: industrieel ontwerpen. (Education audit industrial engineering: industrial design)*, 8 June 2010, BE.

VLHORA, 2012, *Onderwijsvisitatie: Productdesign (Education audit:Product Design)*, 27 Mars 2012, BE.

WYNN D. AND CLARKSON J., (2005) Models of designing, in: Clarkson J & Eckert C,(eds) *Design process improvement: a review of current practice*. Springer Verlag London, page 34-59, UK.

ZEITHAML, V.A., (1988), Consumer Perception of s Price, Quality, and Value: A Means-End Model and Synthesis of Evidence. *Journal of Marketing*, Vol. 52, No. 3, pp. 2-22.

PART I
Design Process Components

PART I:

Design Process Components

The main goal of the research described in this PhD thesis is to identify which design process components of tangible functional products contribute to a better perceived product quality. To be able to determine which components affect the perceived product quality, the components had to be identified first. In this part, the design processes of design students were studied to identify the individual process components. This is described in chapter two. In chapter three the effect of the experience of the design students with the components on the actual application of those components is studied. Thus, part one of this PhD focusses on the upper part of the design process in the perceived product design – quality – model (see Figure I.1).

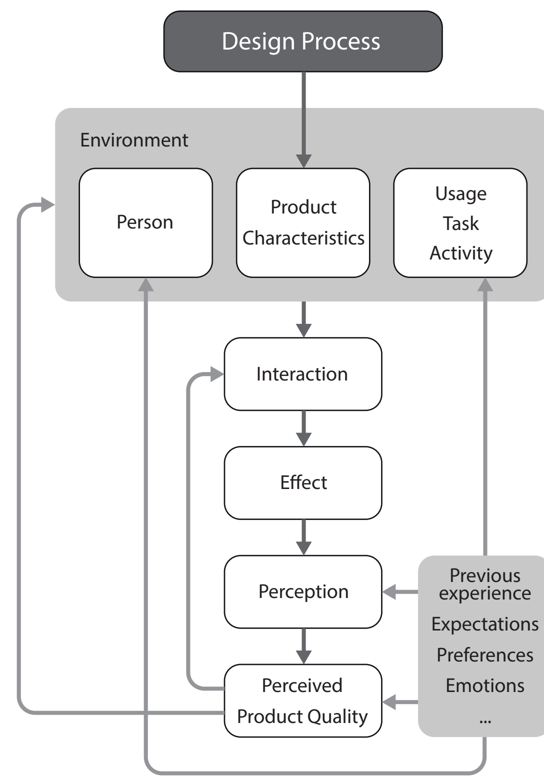


FIGURE I.1: the product – design – quality – model

During the research process the term for the 'design process components' has changed in chapter two and three, describing the earliest studies, the term 'elements in the design process' is used.

CHAPTER 2

Design Process Components

REFERENCE PUBLICATION:

Kok, B.N.E., K. Slegers, and P.Vink, (2011) Methods of the design process: an inventory. *ODAM 10th conference, Grahamstown, South Africa.*

2. Design Process Components

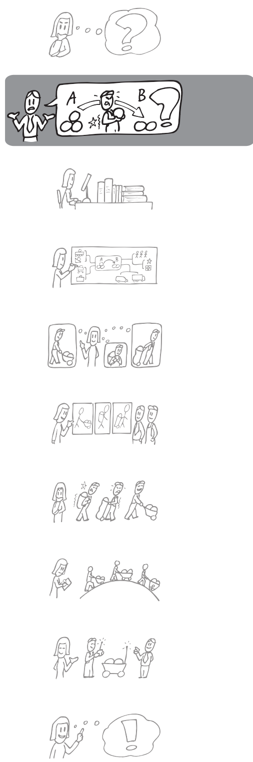
ABSTRACT

Ergonomics, usability and user-centred design are principles that are well known among designers. Yet designers sometimes fail to meet the users' needs and design things people don't understand what it does, nor know how to use. To better understand discrepancy it is necessary to evaluate what steps designers complete during the design process. This research aimed to understand the methods used by designers in practice during the design process. Since it is difficult to obtain design processes of professionals the design processes of student designers were studied. A total of 151 design cases of students in product design were analysed.

KEYWORDS

Design, methods in the design process, design process, design actions

2.1 INTRODUCTION



Since the mid-twentieth century, there has been a growing consciousness of the importance of ergonomics and the need to create products synchronized with the users' needs. Nevertheless Norman stated in 1986 that the design of many products often does not meet the needs of the users. In his work he emphasized the importance of taking into account the users' needs in design. Many different types of studies of user needs have been conducted, such as usability studies (e.g. Dumas, 2007), ergonomic research, which started already in the second World War (e.g. Harel, 2009), and Human-Centered research (e.g. IHCD, 2010). Also, many design tools, design philosophies and societies have been developed to improve the fit of products to user needs. These include, amongst others, user-centered design (e.g. Nielsen, 2010), human-centered design (e.g. Lee, 2006), participatory design e.g. (Schuler, 1993), and design & emotion (e.g. design and emotion, 2010). All of these methods share the same basic goal: obtaining more user oriented design. From this point of view a solid implementation of ergonomics, usability and other user-centred methodologies in design would be expected which should result in products that better meet users' needs and expectations. Nevertheless users' expectations towards products are continue to be not fulfilled (Norman, 2010). For instance, in his research, Kuijk (2009) found a gap between expected and experienced usability. A customer has certain expectations towards the usability of a product. However, once this customer uses the product, his assumptions often turn out to be wrong. Some products are so difficult to use that consumers need assistance to use them, or even return or abandon the product (Ouden, 2006; Steger et al., 2007). To have a clear view on the causes of this failure of the product designer to match the user's needs, it is necessary to know what steps designers take during the design process. When these "methods of the design process" are identified and assessed, possibilities for improvement can be postulated.

This is interesting in several respects. For design research and education it is important to understand which of the methods are used in the design process in reality since this knowledge may expose the possible flaws in the design process that are essential to make products that meet more the user's needs and expectations. Design research can then focus on the causes of these gaps and on how they can be bridged. Additionally, education curriculum can be adapted so that the gaps in the design process can be reduced or eliminated. Finally it is interesting to know how the design process is applied in practice, of which very little is known (Norman, 2010).

2.2 METHOD

In this research the design processes of 151 products designed by 61 students of the Master Product Design Education of the Media Art & Design-faculty (of the Limburg Catholic University College in Belgium) were reviewed. Each of the 61 students conducted between one to six assignments. For these assignments, they were given a domain for the product to be designed as well as certain restrictions such as materials or user groups type of product, type of design problem, etc. An example of such a design assignment was: "Design the ultimate mobile means of communication". For each assignment the students wrote a design report.

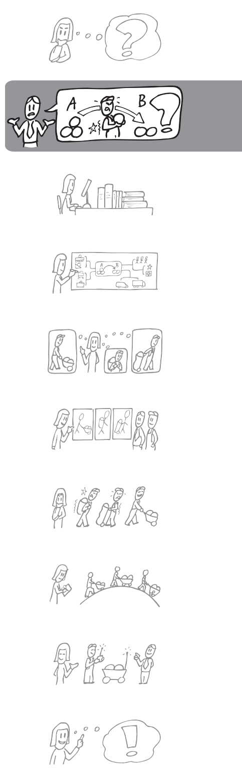
First, in this study all of the elements of the design process applied in the students' design processes were identified. Second, for each project case an inventory of which design elements were used was created. Finally 151 design processes of 61different students were analysed. The cases were a maximum of 3 years old and completed between 2006 and 2010 and were mainly from Bachelor students. Table 2.1 is an overview summary of the participant's specifications. Thirteen different design assignments were studied. The different assignments and the number of cases per assignment are indicated in Table 2.2. The identification of the methods of the design processes that the students used for their assignments was partly based on terms used in other studies (for example "observation"). For the remaining part, the methods were determined by the description of the action taken by the designer and included for example "functional analysis by self-testing".

Table 2.1: case specifications: gender , study level

	NUMBER	%
GENDER		
male	111	73.5
female	40	26.5
SPREADING OF CASES PER STUDY LEVELS		
1 bachelor year	6	4
2 bachelor year	39	26
3 bachelor year	67	44
1 master year	28	19
2 master year	11	7.3

Table 2.2: type of assignment assignments + expected end result

	RE/- NEW DESIGN	END RESULT	NUMBER OF CASES
BACHELOR ASSIGNMENT			
Bachelor graduation project 1st bachelor year (carte blanche)	re-design	concept model/ working prototype	6
Bicycle aid (2nd bachelor)	new design	concept model	10
Sitting element (2nd bachelor)	re-design	concept model	9
Hand tool re-design (2nd bachelor)	re-design	working prototype	20
The ultimate mobile means of communication (3rd bachelor)	new design	concept model	11
Bachelor graduation project (3rd Bach, free assignment)	new design	working prototype	15
interface redesign	re-design	concept model	22
products for dailylife for disabled people	re-design	concept model	19
MASTER ASSIGNMENTS			
Creative technology (1st Master)	new design	working prototype	20
Human Design (1st Master)	new design/ re-design	working prototype	8
Master graduation project (carte blanche)	new design	working prototype	11



2.3 CATEGORIES OF DESIGN METHOS USED IN THIS STUDY

In the research the steps used in the design processes were divided into nine categories. The first category is 'state of the art': did the design student study existing related and non-related products (with similar functionality)? The second category is 'problem solving through literature study or by consulting specialists'. The 'ergonomic and functional study' is the third category: did the design student conduct a study of ergonomic guidelines? Did he perform an analysis of the product functions and tasks? Was an analysis carried out of the risks and of mistakes that users can make with the product? Did he test similar products himself (by using it)? Was the designed product itself tested with respect to these aspects? The fourth category is 'user analysis': what are the needs and wishes of the users? 'Methods used to shaping the design' is the fifth category. The sixth is 'the use of design tools'. In this research design tools are defined as "specific tools and methods used during the whole process or in a particular part of the process in order to improve the quality of the design". Examples of such tools and methods include personas, (Grudin & Pruitt, 2002) and cabinet (Keller, Stappers & Vroegindeweij, 2004). 'User involvement' is the seventh category: were users involved and how? By questioning, observation or asking feedback about concepts and models? The last two categories are 'peer group feedback' and the 'critical attitude (or the lack of it) of the designer student'.

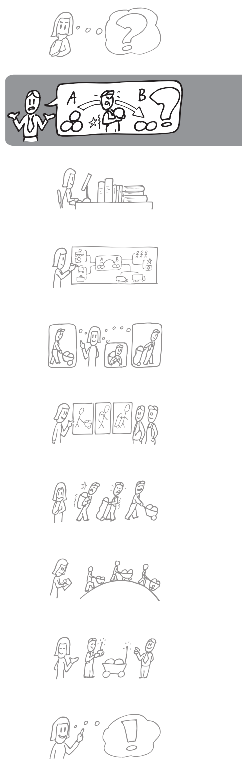
2.4 RESULTS

Table 2.3 provides an overview of all the elements of the design process that were identified in this study. In 144 cases a state of the art of existing similar products was conducted. In 61 cases a state of the art analysis was also conducted of non-similar products in which problems similar to the design problem were solved. In 74 cases a solution research through literature or consulting specialists was done. Literature study was conducted in 60 cases, consulting specialist was done in 51 cases and in 36 cases both were executed. Regarding the ergonomic and functional study, there were consultations of ergonomic guidelines in 111 cases. In 132 cases there was a product function & task analysis (FTA). In 114 a product risk & mistake analysis (RMA) was also executed and in 69 the FTA & RMA was done by self-testing. There were 10 cases in which a product analysis was done by dismantling existing similar products. There is only 1 case in which none of functional analyses mentioned above were conducted.

In the cases, three kinds of shaping techniques were used. Sketching was the most frequently used technique, it was employed in 144 cases. In 117 cases pencil sketching was used, and in 82 cases computer renderings were used. In almost one third (41/151) of the cases the design student made tangible (3D) models during the process. In only 26 cases the use of design tools was reported. For 75 cases it is unknown whether design tools were used or not.

Table 2.3: inventory of the elements of the design process

ELEMENT IN DESIGN PROCES	# EXECUTED	# NOT EXECUTED	MISSING VALUES
State of the art	144	4	3
Similar products	144	4	3
non-relating products	61	87	3
Solution research	74	75	2
through literature (papers etc)	60	89	2
through specialists	51	98	2
Both	36	113	2
Ergonomic and functional study	149	0	2
Consulting ergonomic guidelines...	111	38	2
Product function & task analysis (FTA)	132	16	3
Product risk & mistake analysis (RMA)	114	34	3
FTA & RMA by self-testing (FT-RM-AS)	69	77	5
Product analysis by dismantling	10	139	2
User analysis	113	31	7
Literature	30	40	81
Member of usersgroup (now or near past)	37	33	82
Involving users	62	82	7
Design shaping techniques	144	5	2
2D designing (sketching or rendering)	144	5	2
Sketching	117	29	5
Rendering (CAD)	82	65	4
Tangible models	41	108	2
Design tools	26	50	75
Users' involvement	62	82	7
Questioning users/companion	53	92	6
Observation	41	108	2
Feedback with concepts and/or models	28	123	0
Feedback received by peer Group	69	69	13
Critical attitude	116	33	2
Critical attitude towards FB and gathered info.	116	33	2
FTA & RMA designed product	67	82	2



User analysis was conducted in 113 cases. For 62 cases such an analysis was done by user involvement, for 30 by literature study and in 37 cases the design student was a member of the target group himself. Users involvement in the design process was in 53 cases done by questioning the users -36 cases- or their companions -17- cases when it was not possible to question the user, (for example when designing for users with a severe mental handicap). In 41 cases observations were conducted. The design student asked for feedback on his design by 2D or 3D models in 28 cases. In almost half of the cases (69) the design student received feedback from his college students. Concerning the critical attitude, which was assessed by the coaching teacher, there were 67 cases in which the designed product was analysed for its functionality and usability and in 116 cases the design students had a critical attitude towards the feedback and information he received.

2.5 DISCUSSION & CONCLUSION

The aim of this study was to evaluate what steps designers apply during the design process in order to have a better understanding of the possible causes of the failure of the product designer to match their designs to the user's needs.

In almost each of the cases described in this paper some form of ergonomic research was conducted. This was an expected finding given the relevance of ergonomics to design (Voskamp; 2008, Eger 2010; Dirken, 2006). In most of the cases a state of the art study has been executed. This also was expected since doing such a study is recommended in many design handbooks (Eger 2010; Travis, 2009). User analysis was performed in more than two third of the cases. Several studies have shown the importance of user analysis in product design (Wilson eds., 1997; Travis, 2009), so this finding is also no surprise. Users were also involved in almost half of the cases. This number is somewhat lower than would be expected since ample research has shown the importance of user involvement in design, (Wever, Kuijk and Boks, 2008; Sleeswijk Visser, 2009; Nielsen, 2010; Sanders, 2006). Do design students think user involvement is not useful or valuable or is it too time consuming or perhaps they need guidance to identify and establish user involvment? Also, a higher level of the application of design tools was expected, since there are so many and easily accessible tools available (on websites such as: design and emotion.com, usewell.be, etc.). However, design tools were only been used in one fifth of the cases. A possible explanation for the lack of use of design tools is that the students were not familiar with these design tools. However, this is unlikely as the students were familiarized with the design tools in the second bachelor year which all had completed. Or perhaps the students did not find the tools useful or valuable or they were too time consuming. Maybe the tools are not designed to be user-friendly. Or maybe it is not described in the design report because the students were not aware that some of the methods were design tools.

This study was executed with students cases and may not reflect the design process used by professional designers which is a limitation this study. However, since it is difficult to obtain extensive reports on the design processes of professional designers the analysis of these student cases provided a unique opportunity to study elements of the design processes in a rather large amount of cases. In addition, design student cases provided insight into the way new professional designers may work because, young designers apply the design techniques and methods they learned during their formal education. An additional analysis of methods used in the design process of professional designers should be conducted in order to check whether these conclusions are also valid for professionals.

In these 151 cases most of the elements of the design process were applied in the majority of the cases. Research about the effects of these elements on the designed product still needs to be conducted. Since we do not know the exact reasons why design tools are not used, this should be studied into more detail. Another interesting question is why designer students often don't involve users in the design process. An additional analysis of methods used in the design process of professional designers should be conducted in order to check whether these conclusions are also valid for professionals. Furthermore it is interesting to study in what phase of the design process these methods are commonly used and whether the use of these methods in the design process affects the quality of the designed product This information could be used to improve design tools (usability, publicity, availability etc.). For design research and product design education this is useful for the adjustment of the training, the circulation of the tools an adjustment of the tool itself.

References

DESIGN AND EMOTION, retrieved 20 sept 2011 from http://www.designandemotion.org.

DUMAS, J. (2007) The great leap forward: The birth of the usability profession (1988-1993) *Journal of usability studies* Vol. 2, Issue 2, February 2007, pp. 54-60.

DIRKEN, H. (1997) *Productergonomie: ontwerpen voor gebruikers.* (Product Ergonomics: Designing for Users) Delft, NL, VSSD.

EGER, A., BONNEMA, M., LITTERS, E. , VOORT, M., VAN DER, (2010) *Productontwerpen.* (Product Design) Den Haag, Netherlands, Lemma.

GRUDIN, J. AND PRUITT, J.. (2002), Personas, Participatory Design and Product Development: An Infrastructure for Engagement. *The Participatory Design Conference* (PDC 2002), Sweden, June 23-25.

HAREL, T. (2009) "*The History of Ergonomics*", EasyPublish, Dec 2009, retrieved may 5, 2010, from: http://www.submityourarticle.com

IHCD, (2010), Institute for Human Centered Design, retrieved Dec 18, 2010, from http://www.adaptenv.org/

KELLER, A.I., STAPPERS, P.J., AND VROEGINDE-WEIJ, S. (2004) Supporting informal collections of digital images: organizing, browsing and sharing poster presentation at *Dutch Directions in HCI*, Sigchi.nl, June 2004.

KUIJK, J.I., VAN, PREIJDE, E.E. , TOET, E.N., AND KANIS, H. (2009), Expected versus experienced usability: what you see is not always what you get. *IEA 2009: the 17th world congress on ergonomics*, August 9-14 2009, Beijing, China, IEA.

LEE, L. (2006), *Learning Spaces: Human-Centered Design: Guidelines.* Educause, 2006.

NIELSEN, J., (2010), Usability 101: introduction in usability. *Alertbox*, retrieved may 2010, from www.useit.com

NORMAN, D. (1986) *The Design of Everyday Things.*, New York, USA, Basic Books.

NORMAN, D. (2010), The Research-Practice Gap, *Essays*, retrieved dec 5, 2010, from http://www.jnd.org/dn.mss/the_research-practice_gap_1.html

OUDEN, E., DEN, (2006) *Development of a design analysis model for consumer complaints: revealing a new class of quality failure.* PhD Thesis, TU Eindhoven, The Netherlands.

SANDERS, L., (2006) Design Serving People. Helsinki, Finland, *Cumulus Working Papers*; Publication Series G, University of Art and Design Helsinki.

SCHULER, D. ED, NAMIOKA, A. ED. (1993) *Participatory design: Principles & practices.* Laurence Erlbaum Associated, Inc.

SLEESWIJK- VISSER, F., *Bringing the everyday life of people into design.* PhD Thesis; TU Delft, The Netherlands, 2009.

STEGER, T., B. SPRAGUE AND DOUTHIT, D. (2007) *Big Trouble with No Trouble Found: How Consumer Electronics Firms Confront the High Cost of Customer Returns.* Accenture Communications & High tech, Accenture.

TRAVIS, D., (2009) *The Fable of the USER-CENTRED DESIGNER*, User focus, retrieved dec 20, 2009, from http://www.userfocus.co.uk/fable/

VOSKAMP, P. (2008) *Basisboek ergonomie (Basic Book of Ergonomics)*, Groningen/houten, the Netherlands, Wolters-Noordhoff.

WEVER, R., KUIJK, VAN, J., BOKS C, (2008) User-centred Design for sustainable Behaviour. *International Journal of Sustainable Engineering* Vol. 1, No. 1, 2008.

WILSON S., BEKKER M., JOHNSON P., AND JOHNSON H. (1997), Helping and Hindering User Involvement A Tale of Everyday Design. Queen Mary and Westfield College, London, Electronic Publications: Papers,1997.

CHAPTER 3

Does the Experience in Ergonomics and design Research Tools influence the Application of Design Process Components?

REFERENCE PUBLICATION:

Kok, B.N.E., Slegers, K., and Vink, P., (2012) The Amount of Ergonomics and User Involvement in 151 Design Processes. *Work 41: 989-996*, Brazil.

3. Does the experience in ergonomics and design research tools influene the application of these design process components?

ABSTRACT

Ergonomics, usability and user-centered design are terms that are well known among designers. Yet, products often seem to fail to meet the users' needs, resulting in a gap between expected and experienced usability. To understand the possible causes of this gap the actions taken by the designer during the design process are studied in this paper. This can show whether and how certain actions influence the user-friendliness of the design products. The aim of this research was to understand whether ergonomic principles and methods are included in the design process, whether users are involved in this process and whether the experience of the designer (in ergonomics/user involvement) has an effect on the end product usability. In this study the design processes of 151 tangible products of students in design were analyzed. It showed that in 3/4 of the cases some ergonomic principles were applied. User involvement was performed in only 1/3 of the design cases. Hardly any correlation was found between the designers' experience in ergonomic principles and the way they applied it and no correlations were found between the designers' experience in user involvement and the users' involvement in the design process.

KEYWORDS

Participatory design; applied ergonomics; user involvement; human centred design

3.1 INTRODUCTION

Awareness of the importance of ergonomics and the need to create products synchronized with the users' needs has been growing since the mid-twentieth century. Many different types of studies on taking user needs into account in product design have been conducted, such as usability studies (e.g. Dumas, 2007; Harel, 2009) ergonomic research, which started already in the Second World War and human-centred research (e.g. IHCD, 2010). These studies include several approaches, amongst others user-centred design (e.g. Nielsen, 2010), human-centred design (e.g. Lee, 2006), participatory design (e.g. Haines et al., 2002), design & emotion (e.g. design and emotion, 2011) etc. These approaches share the same basic goal: obtaining more user friendly design, and creating designs which that meet more the user's needs and expectations. Research has also shown the importance of using ergonomic principles and the users' involvement in the design process (e.g. Vink, 2008). From this point of view a solid implementation of ergonomic principles, usability and other user-centred methodologies in design would be expected, resulting in user friendly products that meet the users' needs. Yet products often seem to fail to meet the user's needs. Kuijk (2009) identified a gap between expected and experienced usability in this respect. When buying a product, customers have certain expectations toward the product, which upon use often turn out to be wrong expectations. (Ouden, 2006; Dumas, 2007; Horrigan, 2008; Steger, 2007) Moreover, some products are so hard to use that consumer's need assistance to use them, or even return or abandon the product.

To understand the possible causes of this gap between expected and experienced usability of products, it might be useful to study the actions taken by the designer during the design process that influence the user-friendliness of a product. Clear knowledge of these actions may help to understand whether certain actions influence the usability of the designed products or not. It can also clarify which actions are commonly taken by designers and which are not.

The aim of the research described here was to study the use of ergonomic principles and users involvement in the design process. Secondly, we wanted to understand whether the experience with ergonomic principles and methods of the designer has an effect on the use of these principles and methods in the design process. And thirdly, the effect of experience with using methods for user involvement on the actual involvement of the user in the design process was analysed.

3.2 METHODS

In this study, the design processes of 151 products designed by students of the Master Product Design Education of the Media Art & Design-faculty (of the Limburg Catholic University College in Belgium) were studied. For their assignments the students need to write a report about the design process. In this study the design reports of the 151 cases were analysed.

3.2.1 DESIGN CASES

These design processes were executed by 61 different students. Each student conducted one to six cases. For these assignments, students were given a domain (for example critical design) for the product they had to design as well as certain restrictions (e.g. concerning user group, materials, etc.). An example of such a design assignment is: "Design the ultimate mobile means of communication". All assignments were assessed[1] regarding functionality and usability, the analysis used (e.g. problem analysis user target group, solutions, etc.), the design, technology, innovation and process[2]. The cases were gathered over five years (2006-07 -> 2009-10) and the majority (74%) were from Bachelor students. An overview of the participant's specifications is given in Table 3.1. The 151 cases were retrieved from thirteen different design assignments, the number of cases per assignment vary from two to twenty two[3].

Table 3.1: participant's specifications per case: gender, study level of the participants per case

	NUMBER	%
Gender		
Male	111	74
Female	40	26
Level of education		
1st bachelor	6	4
2nd bachelor	39	26
3rd bachelor	67	44
1st master	11	7
2nd master	11	7

1. The assessments used in this study are the criteria used to assess the projects of students. The assessment were executed by: coaching teachers, a jury of teachers, a jury of users and/or jury of extern designers
2. Retrieved from the self-evaluation Report of the Product Design education (MAD) (Media & Design Academie, 2010).
3. The different assignments and the number of cases per assignment are indicated in Table A I.1 (see Addendum I chapter two).

3.3 CATEGORIES

The report of every case was analysed to determine whether and how ergonomic principles were applied and whether and how users were involved. All design process were further analysed to identify and describe the aspects of ergonomics and user involvement applied in the design process[4].

The aspects of the design processes studied in this research were divided into two categories: 'ergonomic and functional study' (1) and 'user involvement' (2). The category 'ergonomic and functional study' consisted of 'consulting ergonomic guidelines and functional analysis'. The functional analysis consisted of 'product function and task analysis'(FTA), where all the functions of the product were analysed (which actions need to be done, by whom, etc.); 'product risk an mistake analysis' (RMA), where all possible risk of the product and mistakes that can be made by using the product were analysed; 'FTA & RMA by self-testing' (FT-RM-ST), where the designer did the analysis by testing the product himself and 'FTA & RMA designed product', where the designed product was tested itself.

The category' user involvement' was divided into: 'questioning users and/or their companions', (in case the users were for example very small children or have a severe mental disorder[5]); 'observation'; 'feedback on concepts and/or models' (where the participant involved users for testing the concepts and models feedback).

3.3.1 ANALYSIS

In this paragraph some characteristics of the studied group are presented. The level of experience was determined by the study year of the participants. The students have two lesson hours in (product) ergonomics per week during the three bachelor years. The design cases of students in the first year were executed at the end of the first year; the cases in the second year of bachelor were conducted in the first semester and in the first part of the second semester. The participants who executed the cases in the first two years had a low level of experience. The participants who conducted the cases in the third bachelor students had a medium experience in ergonomic principles and the master students had high level of experience.

The level of experience in methods of 'user involvement' was done by studying their curriculum. It appeared that the participants had courses in design methods for user involvement at the end of the second bachelor, the design cases in the second year of bachelor are all executed before these courses began, so they have a low experience in methods for 'user's involvement', in the third year the participants had courses in design methods six hours a week during half a year, they had a medium level of experience. In het following years there were no more specific courses for user involvement, but they had

4. In order to be able to analyse the experience of designs student on their performance of design process components these two categories of design process component were chosen: "ergonomic and functional study" and "user involvement" these two categories were chosen because there is a clear learning path for these categories in the curriculum at that time. The learning path is described in 3.3.1 Analysis § 1. The learning path of other categories is less clear in the curriculum.
5. In some assignment product were created for very small children or mentally disable people, which makes it hard to question the potential users. In these cases the designer student questioned the users companion.

completed the courses in methods in user involvement, they were considered to have a high level of experience. The levels of experience were divided into three groups. The cases performed in the first and second year of bachelor are divided into the group coded a low level of experience, (i.e. low level of experience in ergonomic principles and no experience in methods for user involvement). The distribution of experience of the participants is shown in figure 3.1. To determine the aspects of ergonomic and functional study and user involvement, all steps taken during the design process were identified and analysed. Then, for each case inventories of which of these aspects were used in the design process was made.

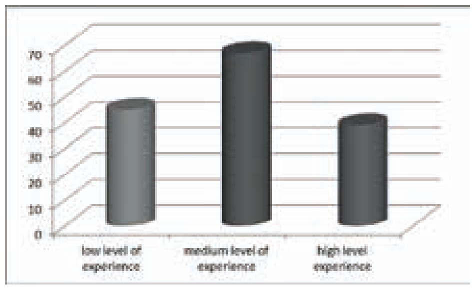


FIGURE 3.1: *number of cases by level of experience*

Thirdly, possible correlations between the participants' experience in ergonomics and the methods used for user involvement were analysed.

In part of the cases one of the supervisors was the teacher in ergonomics (70/151) or the teacher in methods for user involvement (26/151), which could affect the results. To trace possible biases, correlations between the supervision of the teacher in ergonomics and the supervision of the teacher in methods for user involvement were analysed as well.

The statistical analysis was done by crosstabs[6] (in SPSS). The experiences were coded as follows: 1 for a low level of experience, 2 for a medium level and 3 for a high level. When an aspect was performed it was coded 1 if applied (for example users were observed) and coded 0 if it was not applied. The effect of the supervisors expertise (ergonomics or user involvement) and application of ergonomic principles or user involvement was analysed by crosstabs.

6. *Crosstabs are used to analyse hypotheses about how some variables are contingent upon others. Crosstabs are use if the variables level is nominal or ordinal. (Dalen and Leede, 2009) which is the case in this study. The crosstab analyses were performed double edged.*

3.4 RESULTS

Table 3.2 provides an overview of all aspects of 'ergonomic principles' and 'user involvement' identified in this study. In almost every case (145/151) some kind of' ergonomic or functional study' was conducted. In more than two thirds of the cases (111/151) 'ergonomic guidelines' were consulted. In almost 90 % of the cases (132/151) there was a 'product function & task analysis' (FTA). In 75 % (114/151) of the cases a 'product risk & mistake analysis' (RMA) was done. FTA & RMA by self-testing and FTA & RMA designed product were executed in less than half of the cases (both 69 out of 151).

'User involvement' was observed in 42 % of the cases (62/151). In one third of the cases (52/151) 'user involvement' was done by questioning users (36/151) or their companions (17/151). In case it was not possible to question the users (for example when designing for users with a severe mental handicap) or both (1/151). In 27 % of the cases (41/151) 'observations' were performed. The participants asked for 'feedback on their design by concepts and models' in one fifth of the cases (28/151).

Table 3.2: Application of ergonomic principles and user involvement

	EXECUTED	NOT EXECUTED	MISSING	% EXECUTED
Ergonomic functional study	145	4	2	96
Consulting ergonomic guidelines	111	38	2	74
Functional analysis	*134*	*15*	*2*	*89*
Product function and task analysis (F)	132	16	3	87
Product risk and mistake analysis (RM)	114	34	3	75
FTA & RMA by self testing (TF-RM-ST)	69	77	5	46
FTA & RMA designed product	67	84	0	44
Users Involvement	63	82	6	42
Questioning users and/or companion	52	91	8	34
Observation	41	108	2	27
Feedback on concepts and/or model	28	123	0	19

3.4.1 CORRELATIONS EXPERIENCE & USE OF ERGONOMIC PRINCIPLES

The application of 'product function and task analysis' was the same in all groups, about 90 %. There seems to be a difference between the three groups for the 'risk and mistake analysis': in the group with a low level and the group with a high level of experience it seems that a RMA is performed less often (76% & 62%) than in the group with a medium level of experience (84%), but the difference was not significant (χ^2 (2)= 4.743 p = 0.094).

The 'FTA & RMA of the designed product' also seems to be applied more often in the group with medium level of experience (54% versus 42% low level & 31% high level), but this difference was not significant either (χ^2 (2)= 10.828 p = 0.065). A significant difference was found for 'consulting ergonomic guidelines' (χ^2 (2)= 28.629 p = 0.000); this was done more often by the participants with a low level of experience (100% versus 63% medium level & 62% high level), the experience of the designer student has a negative effect on the use of 'ergonomic guidelines'.

The 'FTA & RMA by self-testing' and questioning users and/or companions' was performed significantly more often in the group with a medium level of experience (54% versus 42% low level & 38% high level; χ^2 (2)= 10.828p = 0.004). An overview is given in Table 3.3.

For the use of ergonomic principles, the application differs in the three groups. The 'consultation of ergonomic guidelines' was lower in the groups a medium and high level of experience. For 'RMA' and 'FTA & RMA by self-testing' a significant difference was found between the three groups but could not related to the level of experience since the applications higher in the group with a medium level of experience than in the group with low and high level of experience.

Regarding 'user involvement', significance differences were found between the three groups. For 'questioning users or their companion' and 'user feedback on the designed product' a significant difference was found between the three groups but this could not be related to the level of experience since the application was higher in the group with a medium level of experience than in in the group with a low level and the group with a high level of experience.

Table 3.3: Experience versus application ergonomic principles & user involvement

	low level of exp. (45/151)				medium level of exp. (67/151)				high level of exp. (39/151)				χ^2	df	p
	executed	not ex.	missing	*% executed*	executed	not ex.	missing	*% executed*	executed	not ex.	missing	*% executed*			
ergonomic functional study															
consulting ergonomic guidelines	45	0	0	*100*	42	25	0	*63*	24	13	2	*62*	*28,629*	*2*	0.000**
functional analysis															
product function and task analysis (FTA)	40	5	0	*89*	60	6	1	*90*	32	5	3	*82*	*0.507*	*2*	0.832
product risk an mistake analysis (RMA)	34	11	0	*76*	56	10	1	*84*	24	13	2	*62*	*4.743*	*2*	0.094
FTA & RMA by self- testing (TF-RM-ST)	14	31	0	*31*	40	24	3	*60*	15	22	2	*38*	*10.828*	*2*	0.004**
FTA & RMA designed product (TF-RM-DP)	19	26	0	*42*	36	31	0	*54*	12	27	0	*31*	*5.469*	*2*	0.065
users involvement															
questioning users and/or companion	9	35	1	*20*	33	29	5	*49*	10	27	2	*26*	*13.337*	*2*	0.001**
observation	8	37	0	*18*	18	49	0	*27*	15	23	2	*38*	*5.529*	*2*	0.060
feedback on concepts and/or models	5	40	0	*11*	20	47	0	*30*	3	36	0	*8*	*9.824*	*2*	0.005**

α = 0.05

3.4.2 EFFECT SPECIALISM OT THE SUPERVISORS

To check whether the results were affected by the fact that the participants were supervised by an ergonomist or specialist in methods for user involvement, the possible correlations between the presence of a specialist in the supervisors' group and the application of ergonomic principles or user involvement was analysed.

The supervision of an ergonomist was only found to affect two variables: the application of 'product risk and mistake analysis' (χ^2 (2)= 15.348 p = 0,000) and asking 'users for feedback on the design concepts (2D) and tangible models' (χ^2 (2)= 15.348 p = 0,000) p = 0,035). The 'RMA' is applied in 90 % of the cases, when an ergonomist is part of the supervisors' group and only in 65 % of the other group. Feedback on concepts and models was requested in twice as often (26% versus 12%) cases when there was an ergonomist in the supervisors' group.

The supervision of a specialist in user involvement only affected one variable: 'questioning users or companions' (χ^2 (2)= 10.961 p = 0,001). Users (or their companions) were questioned twice as often in the group with the specialist in the supervisors' group, (65% versus 29%), which is in line with expectations. The frequencies and correlations are shown in Table 3.4.

Table 3.4: Specialism supervisor versus application ergonomic principles & user involvement

	ergonomist									teacher meth. in user involvement								
	supervision (70/151)			no supervision (81/151)						supervision (26/151)			no supervision (125/151)				*df*	*p*
	executed		missing	executed		missing	χ^2	df	p	executed		missing	executed		missing	χ^2	df	p
ergonomic functional study																		
consutling ergonomic guidelines	52	(74%)	0	59	(72%)	2	0.021	1	*0.885*	19	(73%)	0	92	(73%)	2	0.051	1	*-0.821*
functional analysis																		
Product function and task analysis (FTA)	63	(90%)	1	69	(85%)	2	0.528	1	*0.468*	21	(81%)	0	111	(89%)	2	2.103	1	*0.147*
product risk an mistake analysis (RMA)	63	(90%)	1	51	(63%)	2	15.348	1	*0.00***	17	(65%)	0	97	(78%)	3	2.372	1	*0.124*
FTA & RMA by self testing (TF-RM-ST)	36	(51%)	3	33	(41%)	2	1.629	1	*0.202*	12	(46%)	0	57	(46%)	5	0.042	1	*0.838*
FTA & RMA designed product (TF-RM-DP)	25	(36%)	0	42	(51%)	0	0.458	1	*0.498*	15	(58%)	0	52	(42%)	0	2.245	1	*0.134*
Users involvement																		
questioning users and/or companion	24	(34%)	6	29	(35%)	2	0.044	1	0.833	17	(65%)	0	35	(28%)	8	10.961	1	*0.001***
observation	18	(26%)	2	23	(28%)	0	0.287	1	0.592	7	(27%)	0	34	(27%)	2	0.012	1	*0.911*
feedback on concepts and/or models	18	(26%)	0	10	(12%)	0	4.463	1	0.035*	7	(27%)	0	21	104	0	1.353	1	*0.245*

α = 0.05

3.5 DISCUSSION & CONCLUSION

3.5.1 DISCUSSION

The aim of this research was to answer three questions: Are ergonomics principles, methods etc. commonly included in the design process of tangible products? Are users generally involved in this process? And is the designer's experience with ergonomics/user involvement correlated with the application of both ergonomics and user involvement in the design process?

The first question can be answered positively: the use of ergonomic guidelines, the' function & task analysis' (FTA) and the 'risk & mistake analysis' (RMA) was done in 75% of all cases. There was a difference in application in the three groups of different level of experience for 'consulting guidelines' and 'RMA', but it is still performed in more than 60% of the cases in all groups. The 'function, task, risk & mistake analysis by self-testing' (FT-RM-ST) and 'function, task, risk & mistake analysis of the designed product' (FT-RM-DP) was performed in a little less than half of the cases. The 'FT-RM-ST' and 'FT-RM-DP' are time consuming, which could explain why these are performed less often. Such a lack of time was often mentioned in the reports of design processes. The academy, the teachers and supervisors find ergonomics very important, which is shown by the high number of hours in ergonomic courses and the high number of assignments supervised by the teacher in ergonomics (7/16 assignments), (Media & Design Academie, 2010). This could explain why the ergonomic principles are applied in many cases, even though the participants had no experience. Further research is needed on the reasons why some ergonomic principles are applied less often as well as the effect of the application ergonomic principles on the quality of the designed product. In our case we discussed time consumption as one of the reasons, but other reasons could play a role as well; for example implementing the ergonomic principles could strongly influence the designed shapes, (this was sometimes mentioned in the design reports of the participants).

Concerning the question: "Are users generally involved in this process?" it looks like user involvement was less widely performed in the design processes (only in one third of the cases) than the ergonomic principles. This was unexpected since user involvement is important for the academy, (Media & Design Academie, 2010) which is shown by the many course hours in methods for user involvement. The difference between the 'performance of ergonomic principles' and 'user involvement' could be explained in several ways: involving users in the design process requires more effort from designers than applying ergonomic principles; ergonomics and functional studies are widely published, more accessible and more published in the participants' native language (e.g. Eger, 2010, Dirken, 1997, Voskamp, 2008). 'User involvement' also requires a certain amount of time (preparations, making appointments, etc.). The participants often complain about the limited time for their assignments. Oijevaar, (2009) also stated in his research that one of the causes of the lack of 'user involvement' is a result of time limits. The lack of time could also explain why 'user involvement' was mainly done by questioning, (1/3), and less by 'observation' (1/4) and even less by 'feedback on concepts and tangible models' (1/10, see Table 3.2). 'Questioning' was the least time consuming and the easiest way to involve users. Further research is needed on the reasons why users are often not involved as well as the effect of 'user involvement' on the quality of the designed product.

Concerning the correlations, positive correlations were expected between the participants' experience and the application of 'ergonomic principles' and 'user involvement'.
For the use of ergonomic principles the hypothesis that experience influences the application is only partially true. vervangen door: Significant correlations were found between the experience in ergonomics and 'consulting ergonomic guidelines', more experience resulted in less consulting. Contrary to the expectations a negative correlation was found suggesting that the more ergonomic experience designers had, the less they consulted ergonomic guidelines in their design processes. A possible explanation could be that the participants throughout the years became very familiar with the guidelines and have less need to consult those guidelines. In the reports written by the participants with a low level of experience it was often mentioned that these guidelines were a good support during the process, while this is hardly ever mentioned in the reports of the other two groups. For the 'risk & mistake analysis' (RMA) and 'function, task, risk & mistake analysis by self-testing' (TF-RM-ST) a significant difference was found between the three groups which cannot be explained by the level of experience since the application was more frequent in the group with a medium level of experience and less frequent in the group with a high level of experience. The difference between the groups may be partially be explained by the effect of the composition of supervisors. Positive correlations were found for 'RMA' if there was an ergonomist in the group of supervisors. In more than 60 % of the cases in the low and medium level of experience groups were supervised by an ergonomist (see table 3.5). The fact, that in spite of the high number of cases with supervision by an ergonomist, in only one third of the cases in the low experience level group a 'TF-RM-ST' was conducted suggests that the performance of 'TF-RM-ST' was positively influenced by both experience and the supervision of an ergonomist, but further research is needed to confirm this possible correlation. More research is also needed to determine the factors that influence the application of ergonomic principles in the design process.

Table 3.5: Specialism supervisors in different level groups

	SUPERVISED BY SPECIALIST IN	
	ERGONOMICS (70/151)	USER INVOLVEMENT (26/151)
EXPERIENCE LEVEL		
low level of experiencce	6	0
medium level of experience	39	17
High level of experience	25	9
CROSSTAB		
X^2	60.460	49.224
df	2	2
p	0.000	0.000

α = *0.05*

Regarding the 'user involvement', the hypothesis that experiences in 'user involvement' influences the decision to involve users was not supported by this study. Significant differences were found between the three groups for 'questioning users or their companion' and 'user feedback on the designed product'. The number of cases involving users was higher in the group with a medium level of experience and lower in the group with a high level of experience. The participants of the group with a medium level of experience had simultaneous with the design assignments the courses in methods for user involvement, through which they probably paid more attention to 'user involvement'. The participants of the medium experience level group often described importance of 'user involvement' in their reports (in the conclusion). Another possible explanation is the expertise of the supervisors. A positive correlation was found for 'questioning users (or their companions)' and the presence of the teacher in user involvement in the group of supervisors. One third of the cases of the group of medium level of experience was supervised by the teacher in user involvement, (none of the cases in the other two groups were supervised by the teacher in user involvement). The higher number of cases in which users were asked for 'feedback on the design concepts (2D) and tangible models' in the group with a medium level of experience might be explained by both the level of experience and the supervision of an ergonomist, (analogous to the high number of TF-RM-ST in the medium level group), further research is needed to confirm this.
There was a positive correlation between the supervision of an ergonomist and 'asking users for feedback on the design concepts (2D) and tangible models'. More research is needed to determine the factors that influence the user involvement in the design process.
Although this study was executed with students' design cases instead of cases of professional designers, the analysis of these cases provide a unique opportunity to study elements of the design processes in a rather large amount of cases. Especially, since it is difficult to obtain extensive reports on the design processes of professional designers. In addition, design student cases are representative of the way young professionals work because young designers apply the design techniques and methods they learned during their education. General conclusions cannot be made from this study. Since ergonomics and user involvement are important in this academy, it is possible that the participants apply more ergonomic principles and user involvement than professionals or design students from other academies or universities do. Therefore further research is needed in other academies and in the field to come to more general conclusions. Another interesting question is whether all the efforts put into ergonomics and user involvement in the design process really pays off. Are products with attention for ergonomics experienced as better and is the quality of these products better than those without the attention to ergonomics? Further research is highly recommended.

3.5.2 CONCLUSION

The general conclusion is that some ergonomic principles (using guidelines; function & task analysis and risk and mistake analysis) were widely implemented in the design process. Other ergonomic principles (such as: function, task, risk & mistake analysis by self-testing and function, task, risk & mistake analysis of the designed product) are only performed in a less than half of the cases and user involvement is only performed in less than one third of the cases. Research about how education can increase the performance of these ergonomic principles and user involvement is needed. This is important for education so they can adjust the educational program.

Further research is needed on the effect of the implementation of ergonomic principles in the design process on the usability and the user's experience of the designed product, (Dirken, 1997; Eger, 2010; Voskamp, 2008). The performance of ergonomic principles should result in in products that meet more the user's needs and expectations, which are the aim of (product) ergonomics. Analogous the effect of user involvement on usability and the user's experience of the designed products should be studied. Many researchers (Nielsen, 2010; Sanders, 2001) have stated that user involvement in the design process is essential to achieve user friendly design, so it is interesting to find out if the user involvement actually improves the users' experience of the product.

References

DALEN ,J., VAN, AND LEEDE, E., VAN, (2009), *Statistisch onderzoek met SPSS for Windows (statistic research with SPSS for Windows)*,-Lemma, NL.

DIRKEN, H. (1997), *Productergonomie: ontwerpen voor gebruikers.* (Product Ergonomics: Designing for Users) Delft, NL, VSSD.

DESIGN AND EMOTION, (2011), retrieved 20 Sept 2011 from: http://www.designandemotion.org.

DUMAS, J., (2007), The great leap forward: The birth of the usability profession (1988-1993). *Journal of usability studies* Vol. 2, 2, pp. 54-60.

EGER, A., BONNEMA, M., LITTERS, E., AND VOORT, , M., VAN DER (2010), *"Productontwerpen."* (Product Design) Den Haag, Netherlands, Lemma.

HAINES, H., WILSON, J.R. , VINK, P. AND KONINGSVELD, E., (2002), Validating a framework for participatory ergonomics (the PEF). *Ergonomics,* Vol45, 4, pp 309-327.

HAREL T., (2009), The History of Ergonomics, *EasyPublish,* retrieved May 5, 2011, from: http://www.submityourarticle.com.

HORRIGAN, J. B. AND JONES, S. , (2008), *When Technology Fails*. Pew Research Center Publications.

IHCD, (2010). *Institute for Human Centered Design*, retrieved June 2010, from http://www.adaptenv.org/

KUIJK, J.I., VAN, PREIJDE, E.E., TOET, E.N., AND KANIS, H., (2009), Expected versus experienced usability: what you see is not always what you get. *IEA 2009: the 17th world congress on ergonomics*, Beijing, China.

LEE, L., (2006), *Learning Spaces: Human-Centered Design: Guidelines.* Educause.

NIELSEN J., (2010), Usability 101: introduction in usability. *Alertbox*, retrieved may 2010, www. useit.com

NORMAN, D. (1986), *The Design of Everyday Things.* New York, USA, Basic Books.

OIJEVAAR, K.J., JOVANOVIC, M., AND OTTER, A.F.H.J., DEN (2009), User Involvement in the Design Process of Multifunctional Buildings. From Wamelink, H., Prins, M. & Geraerdts, R. (Eds.), *Changing Roles: New Roles and New Challenges*, pp. 485-495, Delft: University Press.

OUDEN, E., DEN, YUAN, L., SONNEMANS, P.J. M. AND BROMBACHER, A.C., (2006), Quality and Reliability Problems from a Consumer's Perspective: an Increasing Problem Overlooked by Businesses, *Qual. Reliab. Engng. Int.*, Vol., 22, pp. 821–838.

STEGER, T., SPRAGUE, B., AND DOUTHIT, D., (2007), Big Trouble with No Trouble Found: How Consumer Electronics Firms Confront the High Cost of Customer Returns. *Accenture Communications & High tech, Accenture*, 2007.

VINK P., IMADA A.S., AND ZINK K.J., (2008), Defining stakeholder involvement in participatory design processes, *Applied Ergonomics, Vol. 39*, pp 519–526.

VOSKAMP, P., (2008), *Basisboek ergonomie.* (basic book of ergonomics), Groningen/houten, the Netherlands, Wolters-Noordhoff.

MEDIA & DESIGN ACADEMIE (2010), *Zelfevaluatierapport* (Self Evaluation Report) retrieved 1 july 2010, from: http://www.hogeronderwijsregister.be/files/50ba7a24461dc_rapport%20KHL%20acad-ba%20Bachelor%20of%20Arts%20in%20het%20productdesign.pdf, Genk, Belgium.

References

BEIRNE, P. (2011), From Object to Objective: Reframing the Goals of Product Design Education in a Postindustrial Context. *IJ Design Principles and Practices, Vol.5, Issue 6, ISSN 1833-1874.*

Discussion Part I

In this first part, the first sub-question "Which components can be distinguished in the design process?" was addressed. In Chapter 2, the design process components that were applied in the design processes of design students were studied. In addition, in Chapter 3, the relationship between design education and design processes was addressed. The correlations found in Chapter 3 indicate that both the educational program (i.e. experience of the design students) as well as the expertise of the coaching teachers had an effect on the design processes of the design students. Other factors that have probably affected the design processes as well could be for example the students' context (the financial context, the machinery at their disposal, the time available to work on the assignment, etc.) and the assessment of the design assignments. Design students are probably more likely to apply design process components which they presume to result in better grades. As mentioned in the introduction the aim of design is to create better everyday experience (Beirne, 2011). The assessment of the products and it's experienced product quality is mainly assessed by teachers. Therefore, it was considered interesting to further study the ability of design teachers to estimate the user experience of the students' products' target users, because design students are mainly assessed by teachers. The ability of design teachers to estimate the users experience is addressed in Part III, Chapter 7.

PART II

The Effect of the Design Process Components

PART II:

The Effect of the Design Process Components

In the previous chapters the components of the design process were defined. Knowing these components is not enough to create efficient design processes resulting in a positive product quality perception. To determine how design education can contribute to a better product quality perception, it is necessary to determine which components in the design process have an effect on the product quality perception. As a result, the components which have a positive effect can get more attention by designers and can be implemented (more) in the design education program. Part II of this PhD focusses on both the upper and lower part of the product design – quality – model (see Figure II.2).

In this part, first an exploratory case study is done to analyse which components in the design process have a positive effect on perceived product quality. Chapter 3 concerns effects of the components in the design process on perceived product quality of products designed for people with special needs. In Chapter 4 the effects of the components in the design process on perceived product quality of products designed for people in general (people with no specific needs or disabilities) is described. Chapter 5 focusses on a specific aspect of product quality: comfort. In Chapter 5, the design processes of seats applied by professional designers are studied. Because an important factor in perceived product quality of seats is comfort, the focus of this Chapter was on comfort and not on functionality and usability, design and ease of maintenance which is the focus in the other studies. In this Chapter the components that are important to obtain comfort (from a professional's point of view) are studied. Additionally, information was gathered on constraints and facilitating factors the designers face in their design process to create comfort in seats.

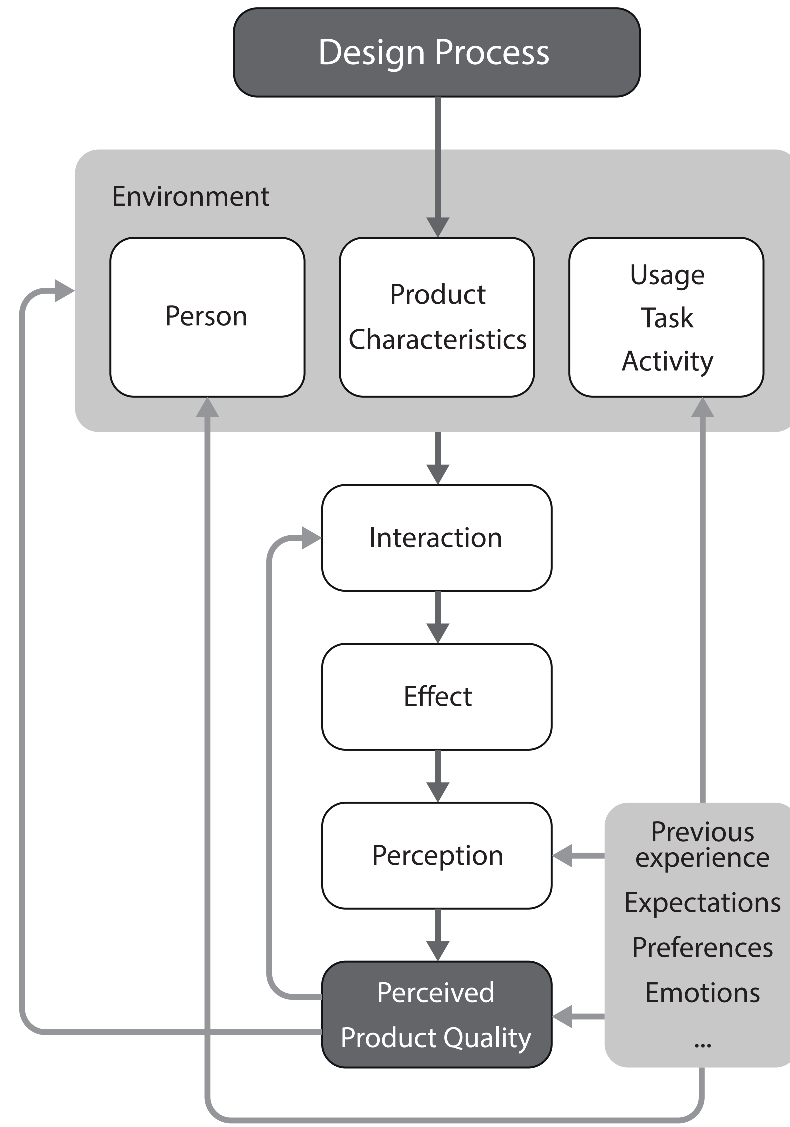


FIGURE II.2: the product – design – quality – model

During the research process the term for the 'design process components' has changed; in Chapter 4 and 6, the term 'components in the design process' is used.

CHAPTER 4

The Effect of the Designer's Approach on the Perceived Product Quality of Tangible Products: an Exploratory Case Study

REFERENCE PUBLICATION:
Kok, B.N.E., Slegers, K., and Vink, P., (2015), The effect of the designer's approach on the perceived product quality: an exploratory case study of tangible products. *The value of Design Research. European Academy of Design conference*, Paris, France.

4. The effect of the designer’s approach on the perceived product quality of tangible products: an exploratory case study

ABSTRACT

Nowadays people tend to value attachment, meaning and experience more than owning even more products. This challenges designers to create products that incorporate more meaning and experience. These kind of products could create a better attachment between user and product, longer use of products and as a consequence less waste. Knowing which steps, methods and tools and other ‘components in the design process’ have an effect on the user experience of the product could help the designer to create such products through implementing these components more into their design process. This paper describes the study in which the correlations between the components of the design process and the user experience by means of three exploratory case studies. Positive correlations were found between the components in the design process and the perceived product quality for components of the categories ‘design shaping methods’, ‘ergonomic and functional study’ and the category ‘user involvement’.

KEYWORDS

user experience, design process, product quality, design methods, human-centred design

4.1 INTRODUCTION

Today’s society is rapidly changing into a society in which people prefer attachment, meaning and experience rather than owning even more products (Dijck, 2007). More and more, people tend to live by the philosophy “less is more”. Parts of society no longer want more products, but better products (Rams, 2013). Designers could respond to this societal change by designing from the philosophy of “more for less”: products that incorporate more meaning and experience will create better attachment between users and products (Dijck, 2007). Such attachment could, in theory, lead to prolonged use of products and, consequentially, to less waste. In order to create attachment between users and products, designers should understand the users of their products, as well as their context and activities, by following a disciplined design process inspired by user research (Norman, 2008). Veryzer and Borja de Mozota (2005) showed the value of user-oriented design for companies. It can help in addressing the realities of application (e.g., customer product use/needs) as well as the realities of the market. Several tools and methods, mostly originating from ergonomics, usability or user-centred design, are available for designers to ensure a good match between their product and the users’ needs, resulting in better user experience. These are available on websites or in guidelines (such as www.designandemotion.org, www.usewell.be, design guide book design methods 1 & 2, Curedale, 2012; universal methods of design, Martin and Hanington, 2012; etc.). Therefore, one might expect that designers commonly apply such tools and methods and succeed in creating usable, useful and desirable products. Unfortunately, many products still don’t fulfill the users’ needs and expectations (Ouden, 2006, Norman, 2010, Nielsen, 2012, Kuijk, et al.,2009). For instance, the research of Kuijk et al. (2009) showed a gap between expected and experienced usability. Customers have certain expectations of the usability of products. However, once customers use products, their assumptions often turn out to be wrong. Some products are so hard to use that consumers need assistance to use them, or even return or abandon the product (Ouden, 2006; Steger et al., 2007). To understand the causes of this gap between what users expect from products and the user experience of these products, it is interesting to study whether the designers approach influences the user experience. The different the steps methods, actions, etc. in the design process could play a role in arriving at user focused products. In order to determine the steps methods, actions, etc. in the design process that are critical for positive perceived quality of the product, we examined how design students applied the design process in projects undertaken as part of their studies in this research. In this research all the steps methods, actions, etc. performed during the design process were defined as 'components of the design process'. The components studied here were divided into five categories based on previous study (Kok et al., 2011).

The categories were categorised as follows:

- 'State of the art': Mapping existing related and non-related products (with similar functionality). The question related to this issue are: Was technology, science and material research conducted?
- 'Design shaping methods': Use of sketching techniques, computer rendering, 3D prototypes and/or working models.
- 'Ergonomic and functional study': Study of ergonomic guidelines. Did the designer perform an analysis of the product's functions and the user's tasks? Was an analysis carried out of the risks and of the mistakes and errors that users can make while using the product? Did she/he test similar products her/himself? Was the designed product itself tested with respect to these aspects?
- 'User involvement': Users involvement in the design process by observation, questioning or user tests? How were users involved? Were they questioned, observed or asked for feedback about concepts and models?
- 'Design research tools': in this category the use of design research tools used (such as cultural probes, ethnographic research…) which the student designers learned to use in the three bachelor years.

When the components of the design process that have a positive effect on the perceived product quality are identified, their influence on users' experience can be estimated and possibilities for improvement can be postulated. This is interesting for several reasons: for design research and education: design research can then focus on how the components, which have positive effects on the perceived product quality can more easily applied. Education can be adapted so that flaws in the design process can be reduced or eliminated. Finally it is interesting to know how the design process is applied in practice.

The study described in this paper explores the components of the design processes of design students. More specifically, it is focused on the effect of these components on the perceived quality of the resulting products. Identifying which of these components elicit a positive effect on the perceived product quality may help designers to improve their products. In this research three exploratory case studies are studied: a 'mobile toy cabinet' for hospitalized children, a 'washbasin for nursing home hairdressers' and the design of a 'personal aid'[7].

4.2 RESEARCH GOAL

The goal of this study was to analyse the effect of the components (steps, tools & methods and others) in the design process on the perceived product quality of the resulting products. The components are classified in to five categories (described in the methods section). A positive effect on the perceived product quality was expected for the category 'state of the art', performing a state of the art analysis of (non) similar products, technology and materials analysis gives designers information about the possibilities and limitations, of the technologies, science, materials etc., and give, amongst others, an idea of the line of thought other designers had concerning similar design problems. Ideas and solutions created by others can inspires people to find new ideas and solutions (Belliston and Belliston, 2000), Similarly the category of 'ergonomic and functional study' is expected to have a positive effect. 'Ergonomic and functional study' increase the usability (Dirken, 1997, Daams, 2011), which often leads to better user experience. Several methods exist to visualise and shape the product during the design process. These methods not only serve to visualise and communicate about the product, but they also are part of the creative process of the designer. Shaping the design, for example by sketching or by making tangible models, stimulates the designer's creativity, (Kuyper, 2005; Cattanach, 1999; Cross, 2006), consequently positive effects on perceived product quality are expected Several researchers (Nielsen, 2010; Sanders, 2006) have stated that user involvement in the design process has a positive effect on the perceived product experience. Therefore user involvement throughout the design process was expected to have a positive effect on the user experience of the designed product. Finally the use of design research tools was expected to have a positive effect on the perceived product quality. Using 'design research tools' can for example stimulate the designers' creativity in finding new strategies etc. to tackle the design challenge or it can enable the designer to gain a better understanding of, for example, how users experience products or certain aspects of products, of the context of the users, of their lifestyle, or of the circumstances in which the users experience certain products useful (Dirken, 1997; Daams, 2011; Curedale, 2012).

7. These 3 cases are treated as one case, analyses showed no significant differences in applying the design process components in the three cases, see Addendum II.

4.3 METHODS

4.3.1 DATA SET

All three case studies, ‘mobile toy cabinet’ for hospitalized children, ‘washbasin for nursing home hairdressers’ and ‘personal aid’ were assignments carried out by bachelor students in Product Design, at the Luca School of Arts, Belgium.

4.3.1.1 MOBILE TOY CABINET FOR HOSPITALIZED CHILDREN

In the case study of the ‘mobile toy cabinet’ for hospitalized children (five to nine years of age) the design processes of five products, created by second year bachelor design students were studied. The final result that the students had to deliver was a scale model of the designed product that demonstrated each of the functionalities of the design. Features that the students could not implement in the model (for example image projections) were illustrated by means of PowerPoint or Prezi presentations .The designs were assessed by two juries of end-users. One jury consisted of hospital staff (five members of the pedagogical staff, a nurse and two doctors), who would be using the mobile toy cabinet in their daily work. The second jury consisted of 20 children, six to eight years old. The data of both juries were used in the analysis.

4.3.1.2 WASHBASIN FOR NURSING HOME HAIRDRESSERS

Third year bachelor design students created six designs for a ‘washbasin for nursing home hairdressers’. The end result had to be a working prototype. The assessment was done by a jury of four hairdressers and one occupational therapist, who all work in a residence for elderly people. First the design students presented the washbasin design and its features (Prezi or PowerPoint). Secondly, the prototypes were tested by the jury members. Afterwards each jury member individually assessed (on paper) each washbasin design by giving a score between 1 and 20.

4.3.1.3 PERSONAL AID

In this cases study eight ‘personal aid’ products were created for a chosen target group. The student designers (all third bachelor year) chose, in consultation with the coaching teacher, a target group with a very specific need for which she/he would create a personal aid (such as for example a product which enables persons with reduced arm and hand force to work with a lathe). The assessment was done by two or three users (of the target group[8]).

8. *For each designed product a jury of 2 or 3 users assessed the product. Due to the specific target groups it was difficult to have larger juries the designs problems addressed by the designers students were amongst others an aid for a musician who plays the violin, guitar and banjo and had his left index finger amputated, a cooking ad for people with severe pain due to advanced rheumatism and other problems. These juries were small because they are difficult to find.*

4.3.1.4 THE JURY ASSESSMENT

To ensure that each jury (of the three cases) would assess the same characteristics of the designed product, the jury members were asked to pay special attention to the functionality and usability (i.e. ease of use, adjustability to each individual user, the extent to which needs and wishes concerning this product were fulfilled), the design (i.e. color, shape, texture,…), and ease of maintenance. The jury of children, in the case study of the ‘mobile toy cabinet for hospitalized children’, were only asked to assess functionality and usability and design. All jury members individually scored (on paper) each design on a scale from 1 to 20. Initially the juries were asked to give a score the functionality and usability, the design and the maintenance separately, as well as a score for the product in general, only two jury members gave scores for the individual aspect, therefore only the general score is used in the analysis. The evaluation by the children(mobile toy cabinet) was done slightly differently. The children were first asked to indicate for each mobile toy cabinet whether it was good enough to be used in a hospital or not, (This was done as a warming up exercise, as advised by the teacher, because the children do not often give scores). Secondly they were asked to assign a score on a scale from 1 to 20 for each designed product, and only this second score was used in the analysis. A scale of 20 was used because a part of the data of this study is also used in another study in which the ability of designer teacher to estimate the user product experience. In Belgian University Colleges the students (where this study was conducted) assignments are usually scored on a scale of 20.

4.3.2 STUDY DESIGN

Two type of data were collected, the components of the design processes of the students and the assessments of the designed products by the jury members.

4.3.2.1 DATA COLLECTION OF COMPONENTS IN THE DESIGN PROCESS

Based on the categories, described in the introduction, a survey was created that the design students in the three case studies had to complete after the presentation of their designed product. Based on the data collected with this survey, the components of each design process were mapped and scored, (‘0’ when the component was not applied and ‘1’ when it was applied by the participant). Figure 4.1 shows some examples of the components in the design process.

FIGURE 4.1: left side: examples of user involvement: feedback on 2D models, right side examples of the FT- RM-A by self-testing

4.3.3 STATISTIC ANALYSIS

The data were analysed in SPSS. First a Kruskal-Wallis[9] exact test was executed to find possible significant differences in the scores for the designed product the three cases 'mobile toy cabinet', 'washbasin' and 'personal aid', (independent variable: type of design case, dependent variable the score). Also a Mann-Withney[10] exact two sample test was executed to find possible significant differences in scores between the second bachelor and third bachelor year students designs processes (independent variable: study level student designer, dependent variable the score). Because a relatively small number of design processes was studied and the data consisted of dependent variables, nominal level, (the components) and dependent variable of interval (the score for perceived product quality) a Mann-Withney two sample test exact was done, to analyse which components in the design process had an effect on the scores of the jury.

4.4 RESULTS

4.4.1 ANALYSIS OF THE INDEPENDENT VARIABLES

The mean score for the perceived product quality in the 'mobile toy cabinet' case was 13.40 (SD = 2.302), in the 'washbasin for nursing home hairdressers' case was 14.00 (SD = 3.225) and in the 'personal aid' case was 10.88 (SD = 3.227), (see Table 4.1). In the comparison of the 3 cases no significant differences were found (X^2= 4.024, p = 0.134, see Table 4.2), as a consequence the three case studies are considered as one single case study.

9. Kruskal-Wallis-test is used when the systematic differences between more than two independent samples needs to be studied and:
- the x variables level is nominal (not dichotom) and the y variable level is ordinal
- the x variables level is nominal (not dichotom) and the y variable level is interval or ratio and:
  - o the sample is small
  - o or when one cannot assume the normality of the population. (Dalen and Leede, 2009)

Table 4.1: means and standard deviations per case

CASE	N	MEAN	STANDARD DEVIATION
mobile toy cabined	5	13.40	2.302
washbasin for hairdressers	6	14.00	3.225
personal aid	8	10.88	3.227

Table 4.2: Kruskal-Wallis K-sample of the three test cases

CASE	N	MEAN RANK
mobile toy cabined	5	7.00
washbasin for hairdressers	6	11.90
personal aid	8	12.42
KRUSKAL-WALLIS K-SAMPLE TEST EXACT		
chi-Square		4.024
df		2
exact significance		0.134

α =0.05

The mean score for the perceived product quality for the products designed by second bachelor year students was 13.40, (SD= 2.302), in the third bachelor year was 12.21, (SD= 3.490), (see Table 4.3). In the comparison of the two bachelor years no significant differences were found (U= 25.500, p= 0.402, see Table 4.4). Therefore in this study there is no distinction made in the design processes of the second bachelor year and third bachelor year students.

Table 4.3: means and standard deviations per bachelor year

CASE	N	MEAN	STANDARD DEVIATION
second bachelor year	5	13.40	2.302
third bachelor year	14	12.21	3.490

Table 4.4: Mann-Withney two independent sample test study level

CASE	N	MEAN RANK
second bachelor year	5	11.90
third bachelor year	14	9.32
MANN-WITHNEY 2 SAMPLE TEST EXACT		
Mann-Whitney- U		25.500
exact significance		0.402

α =0.05

10. In statistics, the Mann–Whitney U test (also called the Mann–Whitney–Wilcoxon (MWW), Wilcoxon rank-sum test, or Wilcoxon–Mann–Whitney test) is an non-parametric test of the null hypothesis that two samples come from the same population against an alternative hypothesis. Unlike the t-test it does not require the assumption of normal distribution, and it is nearly as efficient as the t-test on normal distributions. (Dalen and Leede, 2009)

4.4.2 FREQUENTIES OF APPLICATION OF THE COMPONENTS OF THE COMPONENTS IN THE DESIGN PROCESS

Except for some components in the category 'ergonomic and functional study' and the categories 'user involvement' and 'design research tools' the components were widely applied (in more than 3/5 of all design processes, see Table 4.1). The components of the category 'state of the art' one component in the category 'design shaping methods' (2D shaping) and some of the components in the category 'ergonomic and functional study' ('consulting guidelines' and function and task analysis') were applied in almost every design process. From the category 'ergonomic and functional study', the components 'functional, task, risk and mistake analysis self-testing' and 'functional, task, risk and mistake analysis of the designed product' were only applied in less than half of the design processes. Similarly in the category 'user involvement', the components 'Feedback on 2D, 3D and working models' were applied in less than half of the design processes. The 'design research tools' were applied the least, only in one fifth of all processes.

Table 4.5 Components in the design process: frequencies

COMPONENTS IN THE DESIGN PROCESS		FREQUENCY
State of the art (STA)		
state of the art of similar products	18	(95%)
state of the art of non-relating products	19	(100%)
Technology, materials, etc. research	19	(100%)
Design shaping methods (DSM)		
2D (sketching/rendering)	18	(95%)
tangible models	15	(79%)
Working model	13	(68%)
Ergonomic & functional study (EFS)		
consulting ergonomic guidelines	17	(90%)
product function and task analysis (FTA)	17	(90%)
product risk and mistake analysis (RMA)	15	(79%)
FTA & RMA by self-testing	9	(47%)
FTA & RMA designed product	8	(42%)
Users involvement (UI)		
questioning users	15	(79%)
observation	13	(68%)
feedback on concepts and/or models		
feedback on concepts (2D)	7	(37%)
feedback on models (3D)	8	(42%)
feedback on working models	9	(47%)
Design research tools (DRT)		
design research tools	4	(21%)

4.4.3 CORRELATIONS BETWEEN THE COMPONETNS AND THE PERCEIVED PRODUCT QUALITY

The average score was 10.9 on a scale of 1-20. Significant positive correlations, between the application of the components and the perceived product quality, were found for components of the categories 'design shaping methods', 'ergonomic and functional study' and 'user involvement'. (see Table 4.6) In the category 'design shaping methods' a significant correlation was found for the 'design shaping by making tangible (3D) models', ($U=0.500$, $\rho=0.001$). Moderate correlations were found for 'design shaping by making working models', ($U=14.000$, $\rho=0.029$). In the category 'ergonomic and functional study' significant correlations, between the components and the perceived product quality were found for 'product function task, risk and mistake analysis by self-testing', ($U=13.000$, $\rho=0.008$), and for 'product function task, risk and mistake analysis of the designed product' ($U=6.000$, $\rho=0.001$). Significant correlations between the components and the perceived product quality was found in the category 'user involvement' for 'feedback on 2D concepts', ($U=5.500$, $\rho= 0.001$) and moderate correlations were found for 'feedback on tangible (3D) models', ($U=19.000$, $\rho=0.041$) and for 'feedback on tangible (3D) models', ($U=18.000$, $\rho=0.028$). For some components interferences can be suspected: to be able to receive feedback about 3D and working models one needs to create 3D models and working models. Therefore we suspected correlations between the application of the components 'design shaping by making 3D models' and 'feedback on 3D models'; and 'design shaping by making working models' and 'feedback on working models'. To get an indication of possible interferences the correlation between these components was analysed by means of crosstabs: no significant correlation was found between 'design shaping by making 3D models' and 'feedback on 3D models' (χ^2 (1)= 0.456, $\rho = 0.103$) and a strong positive correlation was found for 'design shaping by making working models' and 'feedback on working models' (χ^2 (1)= 0.645, $\rho=0.011$).

Table 4.6 Components in the design process: correlations design process components and user assessment

COMPONENTS IN THE DESIGN PROCESS	FREQUENCY	MEAN RANK	MANN WITHNEY U	ρ
State of the art (STA)				
state of the art of similar products	1	10.00	9.000	0.526
state of the art of non-relating products	19	0.00	/	/
Technology, materials, etc. research	18	0.00	/	/
Design shaping methods (DSM)				
2D (sketching/rendering)	18	10,00	28.000	0.182
tangible models	15	11.97	0.500	0.001**
Working model	13	11.92	14.000	0.029*
Ergonomic & functional study (EFS)				
consulting ergonomic guidelines	17	9.74	12.500	0.573
product function and task analysis (FTA)	17	9.91	15.500	0.842
product risk and mistake analysis (RMA)	15	10.97	6.000	0.001**
FTA & RMA by self-testing	9	13.56	13.000	0.008**
FTA & RMA designed product	8	14.75	6.000	0.001**
Users involvement (UI)				
questioning users	15	9.60	24.000	0.596
observation	13	10.77	29.000	0.416
feedback on concepts and/or models				
feedback on concepts (2D)	7	15.21	5.500	0.002**
feedback on models (3D)	8	13.13	19.000	0.041*
feedback on working models (3D)	9	12.94	18.500	0.028*
Design research tools (DRT)				
design research tools	4	13.00	18.000	0.262

α =0.05

4.5 DISCUSSION AND CONCLUSION

4.5.1 CORRELATIONS BETWEEN THE COMPONENTS IN THE DESIGN PROCESS AND THE PERCEIVED PRODUCT QUALITY

The main goal of the study described in this paper was to determine which components in the design processes of design students' assignments were critical for the perceived product quality.

4.5.1.1 DESIGN SHAPING METHODS

As expected, positive correlations between the components and the perceived product quality were found in the category 'design shaping methods'. Making tangible models can stimulate the designer's creativity and can therefore effect the user's perception of the product quality, as mentioned in the hypothesises. Another explanation could be that making tangible and working models enables the designer to detect possible limitations and opportunities of the design that are not always visible in 2D concepts. The strong correlation between the components 'design shaping methods by making working models' and 'user feedback on working models' could indicate that there were interference between these two components. In order to get more information about the interferences between the components a study with a larger amount of design processes should be conducted.

4.5.1.2 ERGONOMIC AND FUNCTIONAL STUDY

For some of the components strong correlations were found between the components and the perceived product quality. The positive effect on the perceived product quality, found for the component 'functional, task, risk and mistake analysis (FTA & RMA) by self-testing' was expected. Conducting a 'FTA & RMA by self-testing', rather than using results of tests done by others, enables the (student) designers to better understand their product's functions. It enables the (student) designer to experience the possibilities and limitations of the products and the possible difficulties to perform certain actions. It could also inspire the student designers to find new possibilities, in simplifying certain actions or in creating new functions for the product. Being creative is not only a mental process but also a (psycho)motor process (Kuyper, 2005; Cattanach, 1999), using the product may have stimulated the creative process. The positive correlation between the component 'functional and task analysis & risk and mistake analysis of the designed product' (FTA & RMA designed product) was expected as well. When creating new features that solve certain problems one could create new problems which did not occur when the product did not have these features. For the components 'using guidelines' and 'functional and task analysis' no conclusions can be made because they were applied in almost every design process studied. Remarkably the components which have a positive effect on the perceived product quality are conducted the least, (in less than 50%). Further research about how education can encourage designer students to apply more 'FTA & RMA by self-testing' and 'FTA & RMA designed product' is needed.

4.5.1.3 USER INVOLVEMENT

In this category several positive correlations were found, between the components and the perceived product quality, as expected. The strongest correlation was for the component 'user feedback on 2D concepts. This could be explained by the fact that 2D concepts are made in the early phases of the design process and adapting 2D concepts is relatively easy and can be done relatively quickly, compared to adaptations of 3D and working models. Applying user feedback 'on tangible models' and 'on working models' had moderate positive effect on the perceived product quality. Which is in line with what Daams (2011) and Dirken (1997) stated: users often have different

product images than designers which can result in different and even wrong interpretations of features and functions. Using 3D models and working models for feedback also enables the designers to analyse how users interpret the product and its features and to adapt the product and its features in order to reduce miss-interpretations.
Similar to the category 'ergonomic and functional study' the components which have a positive effect are applied the least (less than 50%). Further research about how education can encourage designer students to apply more user involvement is needed.

4.5.1.4 DESIGN RESEARCH TOOLS

When looking at the category design research tools two things stand out: no correlations between the 'Design research tools' and the perceived product quality were found and the 'design research tools' were the least applied of all components analysed in the design processes. Lack of time is one possible explanation, applying design research tools' often require effort and time. Students often complained about the limited time for their assignments (this was often mentioned when submitting the assignment). The low application of 'design research tools is consistent with Kujala's (2003) findings. She concluded, from a review of the literature about design research tools for user involvement, that these tools have generally positive effects, especially on user satisfaction, but that they are costly processes and they require time and effort. More research about the reasons for the low application of design research tools in the design process is necessary.
For the components for which no effect was found in this study at least three explanations can be given: (1) the components really had no effect, (2) no correlations could be detected because the component was used in (almost) every case (such as 'state of the art of non-similar products'), and did not differentiate between outcomes, (3) the single component had no effect but certain combinations of components together could affect the results by interference. To analyse such interferences a study with a larger number of design processes should be conducted.

4.5.1.5 STUDY DESIGN

This study was not an in-depth study, but an exploratory case study. Further research with a larger amount of data is needed to analysis whether these results are still valid. The product assessment is conducted only in an early stage (the products are not (yet) on the market). The results give an indication of how users experience these products, but to come to more solid conclusions further research is needed. Secondly this study was executed with student designers, which makes generalisation to the complete designer group difficult. However, since it is difficult to obtain extensive reports about the design processes used by professional designers, analysing these cases could generate knowledge on the components applied in the design process.

Analyses of professional design processes of designers of different schools should be conducted in order to generalise the results. Additionally the design processes and its effect on the perceived product quality of different kind of products are studied. Different products could have different benefits of the components in the design process. Finally the number of users in the jury was also rather small. The scores used in the analysis were for the designed product in general, this could have biased the results, different jury member might value different aspects, of the design as more important. For example if a product which is easy in us and has a good design but is difficult to maintain might have a different general score if the jury member considered maintenance important or if she/he doesn't. The results should be interpreted as a first indication of the effect of the design process on the user experience. In order to get a better view on the effect of the components of the design process on the user experience further research with larger sample and a larger jury is required.

ACKNOWLEDGEMENTS
This study could not have been executed without the collaboration of the students and teachers in Product Design, LUCA School of Arts, and the end-users involved in the assessments. The authors would like to thank them for their contribution.

References

BELLISTON, L., AND BELLISTON M. (2000), *Creatieve intelligentie.* (Creative intelligence). De kern, Baarn, NL.

CATTANACH, A., E., (1999), *Process in the Arts Therapies.* Jessica Kingsley Publishers, UK.

CUREDALE, R., (2012), *Design Methods 1: 200 Ways to Design Thinking.* Design Community College inc., USA.

CROSS, N., (2006), *Designerly ways of Knowing.* Springer Verlag, London, UK.

DALEN, J., VAN, LEEDE, E., VAN, (2009) *Statistisch onderzoek met SPSS for Windows (statistic research with SPSS for Windows)*, uitgeverij Lemma, NL.

DAAMS, B., (2011), *Productergonomie: ontwerpen voor nut, gebruik en beleving.* (product ergonomics: designing for usefulness, use and perception.) Undedisining, NL.

DIJCK, F., VAN, (2007), *Het merk mens: Consumenten grijpen de macht.* (the brand human: consumers seize power) Terra – Lannoo, BE.

DIRKEN, H., (1997), *Productergonomie: ontwerpen voor gebruikers.* (Product ergonomics: designing for users) Delft, NL, VSSD.

KOK, B.N.E., SLEGERS, K., AND VINK, P. (2011), Methods of the design process: an inventory. *Human Factors in Organizational and Management* X, Grahamstown, SA.

KUJALA, S., (2003), User involvement: A review of the benefits and challenges. *Behaviour & Information Technology* 22 (1): 1-16.

KUIJK, VAN, J.I., PREIJDE, E.E. , TOET, E.N., AND KANIS, H. (2009), Expected versus experienced usability: what you see is not always what you get. IEA 2009: *the 17th world congress on ergonomics.* Beijing, China.

KUYPER, A.,(2005), *De functie van linker en rechter hersenhelft.* (the function of the left and right side of the brain). Synergy at Work), NL.

MARTIN, B., AND HANINGTON, B., (2012), *Universal methods of design.* Rockport publisher, USA.

NIELSEN, J. (2012), Usability 101: introduction in usability. *Alertbox*, retrieved feb 2012, from www. useit.com.

NIELSEN, J. (2010), Progress in Usability: Fast or Slow? *Alertbox*, retrieved June 2010 from: www. useit.com.

NORMAN, D. (2010), The Research-Practice Gap, *Essays, Technology first, needs last* retrieved from: *the research-product gulf. interactions*, Vol. 17, 2, 38-42, http://www.jnd.org/dn.mss/technology_first_needs_last.html.

NORMAN, D., 2008, *Front to back: Users experience it that way around.* Retrieved from:http://fronttoback.org/2008/04/01/dont-just-design-what-your-users-want.

OUDEN, E., DEN, (2006), *Development of a design analysis model for consumer complaints: revealing a new class of quality failure.* PhD Thesis, TU Eindhoven, NL.

RAMS, D., (2013), Introduction call for papers. *More for Less: Design in an Age of Austerity.* Cumulus conference Dublin, IRE.

SANDERS, L., (2006), Design Serving People. *Cumulus Working Papers;* Publication Series G, University of Art and Design Helsinki, design, Tuusula, Finland, University of Art and Design Helsinki (UIAH).

VERYZER, R.W., MOZOTA, B., DE, (2005), The Impact of User-Oriented Design on New Product Development: An Examination of Fundamental Relationships. *IJPIM* vol. 22, pp.128–143.

CHAPTER 5

Design process Components Essential for Ergonomic Sound Products

REFERENCE PUBLICATION:
Kok, B.N.E., Slegers, K., and Vink, P., (2015), : Components in the Design Process Essential for Ergonomic Sound Products. *Ergonomics in Design.* (submitted 2015)

5. Design process components essential for ergonomic sound products

Applying ‘functional and ergonomic study’, ‘user involvement’ and ‘design research tools’ in the design process can have a positive effect on the perceived product quality.

ABSTRACT

In this research the components in the design process of products which have a positive effect on perceived product quality are studied. It appeared that for the newly designed products, the use of ‘design research tools’ and ‘user involvement through feedback on 2D models’ had a positive relationship with the perceived product quality. The use of ‘ergonomic guidelines’ showed a negative correlation. For the re-designed products, the component ‘product function and risk analysis of the designed product’ had a positive correlation with the perceived product quality.

KEYWORDS
Design process, design, methods, design actions, human-centred design, product quality, design education, user experience

5.1 INTRODUCTION

Historically, one of the main aims of product design has been to analyse the cultural and social context in order to develop products that create progress in the form of everyday experience (Beirne, 2011). The everyday experience of users is, amongst others, influenced by the perceived product quality (PPQ), which is affected by the product characteristics. The latter are a result of the decisions made by the designer in the design process. The products in this study are not (yet) used in daily life, therefore only the PPQ is studied. Studying components in the design process is interesting to establish possibilities for creating products that contribute to a better PPQ, which is the topic of this paper. Identifying which components in the design process (DP) are positively related to the PPQ could help designers to improve their DP.

5.1.1 PERCEIVED PRODUCT QUALITY

In the literature PPQ is defined as the consumer’s judgment about a product’s overall excellence or superiority, (Tsiotsou, 2006; Bei and Chiao, 200; Zeithaml,1988).This study focused on the ergonomic part of the PPQ. Ergonomics focusses amongst others on efficiency (Daams, 2011). The functionality and usability and maintenance of a product affect the efficiency of product use, therefore these aspects are a part of the PPQ studied. The design (aesthetics, shape, colour, texture, etc.) is also included in the aspects of PPQ studied because, as shown in for instance the study of Sonderegger and Sauer (2010), the appearance of the product can have a positive effect on performance, leading to reduced task completion times.

5.1.2 DESIGN PROCESS

Studies about DP often address a specific design phase, (i.e., Gonçalves et al. 2014; Bender and Blessing, 2004), a specific design problem (i.e., Daalhuizen, 2014), a specific product (i.e. Opsvik, 2008), or a specific design method (i.e., Kujala, 2003). This study focusses on the total DP.
This study was based on the DP of design students. A first attempt to gather information about the DP of professional designers proved to be extremely challenging. Contacting design institutes to distribute surveys to their graduated students, and asking professionals personally to fill in the survey (at conferences, interest groups, etc.). resulted in a low response rate (a dozen responses) which was too low for analyses.

Previous studies have shown that five categories of the components in the DP are potentially relevant to ergonomic aspects in the PPQ. Therefore, these groups of components are used in this paper as well (see Table 5.1): these categories are: ‘state of the art’, ‘design shaping methods’, ‘ergonomic &

functional study', 'users involvement' and 'design research tools'. Because the approach of the DP of re-designed products (RD) and newly designed (ND) can be different and because people have different expectations towards both product categories (Eger, 2007) in this study RD and ND are distinguished.

Table 5.1: Categories of components in the design process

State of the art
state of the art of similar products
state of the art of non-relating products
technology, science (social science, etc.), materials etc. research
desk research
consulting specialists
Design shaping methods
sketching
rendering
designing by making tangible models (3D)
designing by making working models
Ergonomic & functional study
consulting ergonomic guidelines
product function and task analysis
product risk and mistake analysis
product function, risk and mistake analysis by self-testing
product function, risk and mistake analysis of the designed product
Users involvement
questioning users
questioning users companions
observation
feedback on concepts (2D)
feedback on models (3D)
feedback on working models
Design research tools
design research tools

5.2 RESEARCH GOAL AND HYPOTHESIS

The main research goal of this study was to analyse the influence of various components in the DP on perceived (ergonomic) product quality (PPQ). For this purpose, five hypotheses were formulated. First, a positive effect on PPQ was expected for performing a 'state of the art'. Such an analysis provides the designer with information about the possibilities and limitations of available technology, materials etc., (Eger et al, 2010), and can give an idea of the lines of thought other designers had concerning the design problem. Second a positive effect on PPQ was expected for using 'ergonomics and functional study'. Much ergonomic literature, explicitly aimed to increase the usability and functionality of products and shows the advantages of applying ergonomic principles (such as Dirken, 2006; Daams 2011), is readily available for designers. Also the participants (students) are trained in applying, ergonomic principles and usability, (LUCA-arts, 2015). Therefore, such principles and guidelines are expected to be frequently used by student designers and to have a positive effect on PPQ. Third, several methods have been developed to visualise and shape a product during the DP. These methods not only allow designers to visualise and communicate about their designs, but techniques such as sketching or making tangible models stimulate the creativity of the designer (Kuyper, 2005; Cattanach et al., 1999). Users often expect innovation in new products and innovation is more likely to happen if the designer is more creative. Therefore, positive effects were expected for such methods on PPQ, for ND. Fourth, user involvement in the DP was expected to have a positive effect on PPQ. As mentioned in literature (e.g. Nielsen, 2010; Sanders, 2006) user involvement in the DP has a positive effect on the PPQ. User involvement enables the designer to better understand, for example, the users' lifestyles or the circumstances in which they will use a product, and how users experience products or certain aspects of products (Dirken 2006, Daams, 2011). The category 'user involvement' includes questioning users (interviews), observation and user feedback. Finally, the use of 'design research tools'(DRT), (such as Cultural probes, heuristic evaluation, performance etc.), was expected to have a positive effect on PPQ, especially for ND. DRT create the opportunity to improve the design in a structured and creative way and they create the opportunity to take a different (out of the ordinary) view on the design problem, (Martin and Hanington, 2012, Curedale, 2012). This can create new design solutions to the design problem, which can increase the PPQ.

5.3 METHODS

5.3.1 DATA SOURCE

Data were collected from a total of 62 DP conducted by 45 students of a Master in Product Design during a period of 4 years (between 2009-2010 and 2012-2013). For some students, data of multiple design assignments were included. For most students one or two DPs were analysed (see Table 5.2).

Table 5.2: Number of products designed per student

	NUMBER	% PRODUCTS
1 product	31	*50*
2 products	12	*39*
3 products	1	*5*
4 products	1	*6*

The participants were students from second and third bachelor year (average age: 20 years) or the first or second master year (average age 22 years) as shown in Table 5.3. The 62 DP included in this study originated from 12 different design assignments for which students had to design a product. For each of these assignments, students were given a domain as well as certain restrictions (e.g. concerning user group, materials, etc.). An example of such a design assignment was: 'Design the ultimate mobile means of communication'. The assignments and the number of DP per assignment that were included in this study are listed in Table 5.4.

Table 5.3: Case specifications: gender, study level, number of products per student

VARIABLE	PERCENTAGE
GENDER	
male	44 (70%)
female	18 (30%)
LEVEL OF EDUCATION	
1st bachelor	0
2nd bachelor	36 (58%)
3rd bachelor	19 (31%)
1st master	2 (3%)
2nd master	5 (8%)

Table 5.4: type of assignment assignments + expected end result

	RE/NEW DESIGN	END RESULT	NUMBER OF PRODUCTS
BACHELOR ASSIGNMENT			
Bicycle aid	re-design	working prototype	16
Camera support for making pictures at 2.5 m height	new design	concept model	10
Sitting element	re-design	concept model	3
Hand tool re-design	re-design	working prototype	2
The ultimate mobile means of communication	new design	concept model	1
Free assignment bachelor graduation	new design	working prototype	9
Interface redesign	re-design	concept model	1
Product for daily life for disabled people	re-design	concept model	2
mobile toy cabinet for hospitalised children	new design	concept model	5
wash basin for hairdressers	re-design	working prototype	6
MASTER ASSIGNMENTS			
assignment Designers against aids	new design	working prototype	2
Free assignment; master graduation	new design	working prototype	5

To analyse possible differences between RD and ND, the DP were divided into two subgroups: a group of processes in which an existing product was re-designed and improved (RD, 27 products), and a group concerning ND (35) (see Table 5.4).

5.4 STUDY DESIGN

Two types of data were collected: the individual components that were identified in the DP and the assessment of the designed products in terms of PPQ by a jury of expert evaluators.

5.4.1 COMPONENTS IN THE DESIGN PROCESS

The categories of components in the DP that were identified based on a previous study (see Table 5.1) were used to create a survey to identify which components were applied in each of the students' DPs. The students completed the survey after the final presentation of their product.

5.4.2 ASSESSMENT OF THE PERCEIVED PRODUCT QUALITY

The PPQ of the products that were included in this study was assessed by a jury of expert evaluators (3-10 persons). These juries of potential users were composed for each assignment. For example, the jury in the 'bicycle learning aid' assignment were parents who have children who were learning to ride a bike. The jury members were not involved in the DP itself.

The jury of user expert evaluators was established rather than an professional expert jury, as the goal of the study was to assess the relationship between DP components and users' PPQ. Research has shown that the main limitations of professional expert evaluators are related to the inadequacy between the professional experts and the problems reported by users (e.g. Lallemand, Koenig and Gronier, 2014).

The students presented their products to the jury of (user) expert evaluators. The presentations consisted of a prototype or a scale model demonstrating all product functions as well as a presentation (e.g. PowerPoint and Prezi) of the features that the students could not implement in the prototype/model. After seeing the presentations, the jury individually and anonymously assessed the products on a scale of 1 to 20 (in Belgium the university (college) education assessment is always done on a scale of 20, 1 is bad 20 is extremely good). To ensure that the jury members assessed the same characteristics of the designed products, the functionality and usability, the design and the ease of maintenance, (see BOX 5.1). Each sub-question was on one page (format A5) and at the bottom " /20" was added to indicate the score for each aspect. All members of the juries gave a score for PPQ in general (all three aspects together). Unfortunately, although the evaluators gave feedback and comments for each the three different aspects, less than 25% of the jury members gave scores for the three separate assessments aspects. So, only the general scores were used in this study.

BOX 5.1: INSTRUCTIONS AND QUESTIONS FOR THE ASSESSMENT FOR THE JURY OF EXPERT EVALUATORS

What is your assessment of the functionality and usability : ease of use, adjustability, the extent to which expectations concerning this product are fulfilled, etc.?

What is your assessment of the design: colour, shape texture etc. of the product

What is your assessment of the ease of maintenance?

Pleas add your feedback and a score for each of these items.

What is your assessment of the perceived product Quality (focussing only on the functionality and usability, design and the ease of maintenance)?

5.5 STATISTICAL ANALYSIS

The data were analysed in SPSS version 21. The independent variables, i.e. the components in the DP, were coded 1 when applied and 0 when not applied. The dependent variable, the evaluators' assessments, was an interval level variable, allowing for a regression analysis[11]. Analyses were done for all products together and for the RD and ND separately.

5.6 RESULTS

5.6.1 FREQUENCIES OF THE COMPONENTS IN THE DESIGN PROCESS

Most of the components in the DP that were included in this study were applied in more than half of the DP, except for the components in the category 'design research tools' (DRT) and 'user involvement' (these were applied in less than 44% of the cases, see Table 5.5). Two components were applied in almost every DP (> 94%): 'state of the art of similar products' and 'design shaping by sketching'.

11. Regression analysis is a statistical process for estimating the relationships among variables. The focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed.

Table 5.5: Frequencies of the components in the design process

COMPONENTS IN THE DESIGN PROCES	ALL PRODUCTS (62)	RE-DESIGNED PRODUCTS (27)	NEW DESIGNED PRODUCTS (35)
State of the art			
State of the art of similar products	59 (95%)	27 (100%)	32 (91%)
State of the art of non-relating products	40 (65%)	13 (48%)	27 (77%)
Technology, science(social science, etc.), materials etc. research:			
desk research	37 (60%)	5 (19%)	32 (91%)
consulting specialists	28 (45%)	4 (15%)	24 (69%)
Design shaping methods			
sketching	58 (94%)	27 (100%)	31 (89%)
rendering (CAD…)	33 (53%)	11 (41%)	22 (63%)
tangible models	39 (63%)	22 (82%)	17 (49%)
Working model	29 (47%)	10 (70%)	10 (29%)
Ergonomic and functional study			
Consulting ergonomic guidelines...	52 (84%)	25 (93%)	27 (77%)
Product function & task analysis (FTA)	58 (94%)	26 (96%)	32 (91%)
Product risk & mistake analysis (RMA)	41 (66%)	21 (78%)	20 (57%)
FTA & RMA by self-testing	27 (44%)	15 (56%)	12 (34%)
FTA & RMA designed product	38 (61%)	20 (74%)	18 (51%)
Users involvement (UI)			
questioning users	21 (34%)	8 (30%)	13 (37%)
questioning users' companion(s)	19 (31%)	7 (26%)	12 (34%)
observation	28 (45%)	13 (48%)	15 (43%)
feedback on concepts and/or models			
feedback on concepts (2D)	15 (24%)	5 (19%)	10 (29%)
feedback on models (3D)	12 (19%)	5 (19%)	7 (20%)
feedback on working models	27 (44%)	19 (70%)	8 (23%)
Design research tools			
Design research tools	25 (40%)	7 (26%)	18 (51%)

5.6.2 CORRELATIONS BETWEEN COMPONENTS IN THE DESIGN PROCESS AND PERCEIVED PROCESS

The average user scores for all the assessed design products was 13.16 (SD= 2.99) on a scale of 1-20. Significant positive correlations in the regression analysis ($R^2(3)$: $\rho = 0.316$) were found between three components in the DP and PPQ, see Table 5.6). Products for which the students used the component DRT in the DP received an score that was 1.3 (SD= 0.65) points higher than the average score. Products that were designed while using the component 'user feedback on 2D concepts' received a score that was 1.77 (SD= 0.77) points higher than the average score. The application of the component 'functional, task, risk and mistake analysis by self-testing' received a score that was 2.28 (SD = 0.66) points higher than the average score.

Table 5.6: correlations between components in the design process and perceived product quality all design processes

COMPONENT IN THE DESIGN PROCESS	B	SD	p
Intercept	11.209	0.480	≥0.000
ERGONOMIC & FUNCTIONAL STUDY			
functional, task, risk and mistake analysis by self-testing	2.278	0.660	0.001
USER INVOLVEMENT			
feedback on 2D concepts	1.768	0.765	0.024
DESIGN RESEARCH TOOLS			
design research tools	1.321	0.650	0.047
$R^2(3)$: $p = 0.316$, $\alpha = 0.05$			

Analysing the DP of RD and ND separately, resulted in different correlations between the application of the components and PPQ (see Table 5.7). For the RD, the average score was 13.5 (SD= 3.03) on a scale of 20. For this group a moderate positive correlation was found in the regression analysis ($R^2(1)$, p= 0.318) for one component: products for which a 'functional, task, risk and mistake analysis of the designed product' was conducted received a score, for PPQ, that was 3.98 (SD= 1.10) higher than the average score.

Table 5.7: correlations between components in the design process and perceived product quality: re-designed subgroup

COMPONENT IN THE DESIGN PROCESS	B	SD	p
Intercept	10.571	0.946	≥0.000
ERGONOMIC & FUNCTIONAL STUDY			
functional, task, risk and mistake analysis by self-testing	3.979	1.099	0.001
$R^2(1)$, $\rho = 0.318$; $\alpha = 0.05$			

For the ND moderate positive correlation in the regression analysis were found between the components in the DP and the PPQ ($R^2 = 0.395$, see Table 6.8). The average score was 12.9 (SD= 2.97) on a scale of 20. Products where 'user feedback on 2D concepts' were applied in the DP received a score that was 2.87 (SD = 0.87) points higher than average; when DRT were used the score was 2.65 points (SD = 0.82) higher than average and 'consulting ergonomic guideline's (such as guideline concerning measurements for body support) decreases the score by 2.2 points (SD = 0.97).

Table 5.8: correlations between components in the design process and the perceived product quality: new design subgroup

COMPONENT IN THE DESIGN PROCESS	B	SD	p
Intercept	12.370	0.864	≥0.000
USER INVOLVEMENT			
UI feedback on 2D models	2.868	0.869	0.002
DESIGN RESEARCH TOOLS			
design research tools	2.650	0.820	0.003
ERGONOMIC & FUNCTIONAL STUDY			
consulting ergonomic guidelines	-2.161	0.971	0.033
$R^2(3)$:ρ = 0.395; α =0.05			

5.7 DISCUSSION AND CONCLUSION

5.7.1 CORRELATIONS BETWEEN THE CATEGORY ERGONOMIC AND FUNCTIONAL STUDY AND THE PERCEIVED PRODUCT QUALITY

The main goal of this study was to analyse the influence of various components in the DP on PPQ. For two of the components studied, 'state of the art of similar products' and 'design shaping by sketching', correlation analysis could not be performed since they were applied in almost every DP. Probably these components are seen as important by the designers. In the analysis of all products (RD and ND) a positive correlation between 'functional, task, risk and mistake analysis (FTA & RMA) by self-testing' and PPQ was found. Conducting a 'FTA & RMA by self-testing', rather than using the results of tests done by others, allows designers to understand the products' functions better. They experience the possibilities and limits of the product and the possible difficulties to perform certain actions. Using the products can inspire the designer in finding new possibilities, to simplify certain actions or to create new functions for the product. This seems a likely explanation for the positive correlation between 'FTA & RMA by self-testing' and the PPQ in the total group. Surprisingly, this correlation was not found in the separate analyses of ND and RD. In the RD subgroup a positive correlation between the 'FTA & RMA of the designed product' and the PPQ appeared, therefore interferences between 'FTA & RMA designed product' and 'FTA & RMA by self-testing' (of existing similar products or product functions) are suspected. Occasional observations showed that students who conducted a 'FTA & RMA designed product' also often conducted a 'FTA & RMA by self-testing' (66%). In order to detect these interferences, a larger dataset of DP is needed.

For the ND a negative correlation was found between PPQ and the use of 'ergonomic guidelines'. In ND users expect new function fulfilment and innovation rather than good ergonomics (Eger, 2007). The use of ergonomic guidelines may have stimulated the students to think in classic and fixed problem solving thought patterns which reduces creativity, resulting in less innovating designs. De Bono (1990) stated that fixed patterns restrain creativity, this could probably explain this negative correlation.

5.7.2 CORRELATIONS BETWEEN THE CATEGORIES USER INVOLVEMENT AND DESIGN RESEARCH TOOLS AND THE PERCEIVED PRODUCT QUALITY

Based on the literature (e.g. Wever et al., 2008; Sleeswijk-Visser, 2009; Nielsen, 2010; Sanders, 2006), components in the category 'user involvement' were expected to have a positive effect on PPQ of the designed products in the analysis of all products combined as well as in the analysis of the newly designed and redesigned products separately. However, positive correlations between the components and PPQ were only found for 'Feedback on 2D concepts' while no correlations were found between the components 'feedback on tangible (3D) models' and 'feedback on working models'. A possible explanation for this may be found in the limited time the students had for their design assignments (6-8 weeks, except for the master graduation projects 6 months). This lack of time may also explain why only few students applied components from the category 'asking feedback on (working) models' in their DP. Adjustments to 3D or working models cost time and money, which students may not have at their disposal. As a result, students sometimes choose not to make (working) models during the DP for testing and user feedback, but to make only a final model, or have too little time to adjust the models after the testing and user feedback. Some students actually reported that certain adjustments were not executed due to a lack of time. Other researchers also found that a lack of time often results in not involving users in the DP, (Oijevaar, 2009; Kujala, 2003).

As expected, the use of DRT, had a positive effect on the PPQ but only in the analysis of all products the separate analysis of ND. DRT can create the opportunity to take a different (out of the ordinary) view on the design problem, (Martin and Hanington, 2012, Curedale, 2012) and by that means improve the design.

For the lack of correlations between PPQ and the other components in this study several explanations can be thought of: (1) no correlations were detected because the components were used in (almost) every case, (2) due to interferences between the components few correlations were found between the single components, but the application of several components together may have had an effect on the PPQ. To detect possible interferences more data is needed. (3) other aspects such all the designers talent can affect the PPQ, but this was not studied in this research.

5.7.3 CONCLUSION AND FUTURE RESEARCH

The data analysed in the study are derived from the DP of a very specific population: design students of a single education institute. Although these results give an indication about the effects of the DP on the PPQ, generalising these results should be handled with care. Further research whit a larger dataset and more differentiated group of participants generalization is needed to generalise the results.

When looking at the hypothesises: the first and third hypothesis (applying the components of the categories 'state of the art' and 'design shaping methods' have a positive effects on PPQ) cannot be confirmed in this study, since no correlations were found. The second hypothesis (applying the components of the category 'ergonomic and functional study' have a positive effects on PPQ), can only be partly accepted: in the RD subgroup, the application 'FTA & RMA of the designed product' has a significant positive effect on the PPQ, and the component 'consulting ergonomic guidelines' has a negative correlation with the PPQ in the ND subgroup. For the other components no correlations were found. Hypothesis four and five (the components in the categories 'user involvement' and 'DRT' have a positive effect on the PPQ) can be accepted for some of the components: 'Involving users by asking feedback on 2D concepts' and applying DRT in the DP have a significant positive effect on the PPQ of ND. Remarkably the frequency of applying the components of these last two categories (DRT and 'user involvement') were rather low (44% or less). Based on these findings more attention on stimulating designer(students) to apply DRT and user involvement in education program can be advised. Analyses of professionals' DP and other student populations (e.g. from different schools and countries) should be conducted in order to generalize the results. Also further research with a larger data set and data on other students and professionals should be conducted to reveal possible interferences between the components is needed.

References

BEI, LT. AND CHIAO, Y-C, (2001), An integrated model for the effect of perceived product perceived service quality, and perceived price fairness on consumer satisfaction and loyalty. Journal of consumer Satisfaction, Dissatisfaction and Complaining Behaviour, Vol 14, pp. 125- 140.

BEIRNE, P. (2011), From Object to Objective: Reframing the Goals of Product Design Education in a Postindustrial Context. *IJ Design Principles and Practices*, Vol.5, 6, ISSN 1833-1874.

BENDER, B., AND BLESSING, L. (2004), On the superiority of opportunistic design strategies during early embodiment design. *8th International Design Conference*, Dubrovnik, Croatia, 117-122

BONO, DE, E. (1990), *Lateral Thinking: Creativity step by step*. Harper& Row, New York, USA.

CUREDALE, R., (2012), *Design methods 1: 200 ways to design Thinking*. Design Community College inc., USA.

DIRKEN, H.,(2006), *Productergonomie: ontwerpen voor gebruikers*, (product ergonommics: designing for users) Delft, NL, VSSD.

DAALHUIZEN, J.J., (2014), *Method Usage in Design: How methods function as mental tools for designers*, PhD thesis, chapter 3,pp. 63-96, TU Delft, NL.

DAAMS, B. (2011) *"Productergonomie: ontwerpen voor nut, gebruik en beleving."* (product ergonomics design for usefulness, use and experience), Undedisining, NL.

EGER, A. O., BONNEMA, M., LITTERS, E. , AND VOORT, M., VAN DER, (2010), *Productontwerpen* (Product Design). Den Haag, Lemma, NL.

EGER, A.O., (2007), *Evolutionaire productontwikkeling* (Evolutionary Product Design), Lemma, NL.

GONÇALVES, M., CARDOSO, C., AND BADKE-SCHAUB,P., (2014), What inspires designers? Preferences on inspirational approaches during idea generation. *Design Studies* Vol. 3, pp 29-53, http://dx.doi.org/10.1016/j.destud.2013.09.001.

HASSENZAHL, M., (2005), Funology From Usability to Enjoyment. in: Blythe, M.A., Overbeeke, K., Monk, A.M., and Wright, P.C. eds. *Human-Computer Interaction Series*, Vol., 3, pp 31-42.

KOK, B. N., SLEGERS, K., AND VINK, P., (2011), Methods of the design process: an inventory. *Human Factors in Organisational Design and Management - X* (pp. 275-280). Grahamstown, South Africa: ODAM.

KOK, B. N., SLEGERS, K., AND VINK, P., (2015), The effect of the designer's approach on the perceived product quality: an exploratory case study of tangible products. *The value of Design Research, 11th European Academy of Design conference 22-24 April 2015*, Paris.

KUJALA, S., (2003), User involvement: A review of the benefits and challenges, *Behaviour & Information Technology,* Vol. 22, 1, pp. 1-16.

KUYPER, A.(2005), *De functie van linker en rechter hersenhelft*, (The Left and Right side Functions of the Brain), Synergy at Work, NL.

LALLEMAND, C., KOENI, G., AND GRONIER, V., (2014), How Relevant is an Expert Evaluation of User Experience based on a Psychological Needs-Driven Approach?, *NordiCHI'14 - the 8th Nordic Conference on Human-Computer Interaction*, At Helsinki, FI

LEE, L. (2006), *Learning Spaces: Human-Centered Design: Guidelines.* Educause.

MAD-FACULTY, (2010) *"Zelfevaluatierapport Productdesign" (Self-evaluation report Product Design)*, Genk, BE.

MAD-FACULTY, (2014) *"Studieprogramma Productdesign" (study program Product Design)*, retrieved Feb. 2014 from: www.mad-fac.be.

MARTIN, B., AND HANINGTON B., (2012), *Universele ontwerpmethoden* (Universal methods of design), Texcase, Utrecht, NL.

NIELSEN, J. (2012), Usability 101: introduction in usability. *Alertbox*, retrieved Jan. 2012 ,from www. useit.com.

NIELSEN, J. (2010), Progress in Usability: Fast or Slow? *Alertbox* ,retrieved feb. 2010, from www. useit.com.

NORMAN, D. (2010), The Research-Practice Gap, *Essays & Technology first, needs last: the research-product gulf.* Interactions, Vol 17, 2, pp. 38-42, http://www.jnd.org/dn.mss/technology_first_needs_last.html.

OIJEVAAR, K.J., JOVANOVIC, M. , AND OTTER, A.F.H.J., VAN DER, USER INVOLVEMENT IN THE DESIGN PROCESS OF MULTIFUNCTIONAL BUILDINGS. IN WAMELINK, H., PRINS, M. & GERAERDTS, R. (EDS.),(2009), CR09, Changing Roles: New Roles and New Challenges, (pp. 485-495). Delft: University Press, NL.

OPSVIK, P. (2008). *Rethinking Sitting.* Oslo, Norway: Gaidaros Forlag SA.

SANDERS, L., (2001), *Collective Creativity, nr 3, LOOP* American Institute of Graphic Arts, Virginia Commonwealth University Center for Design Studies, , USA.

SANDERS, L., (2006), Design Serving People. *Cumulus Working Papers; Publication Series G*, University of Art and Design Helsinki. Design, Tuusula, Finland.

SLEESWIJK-VISSER, F., (2009), *Bringing the everyday life of people into design.* PhD Thesis; TU Delft, The Netherlands.

SONDEREGGER A. AND SAUER J., (2010), The influence of design aesthetics in usability testing: Effects on user performance and perceived usability. *Applied Ergonomics*, Vol. 41, 3, May 2010, pp.403–410.

TIEMEIJER, W.L., THOMAS, C.A., PRAST, H.M. (RED), (2009), *De menselijke beslisser* (the human decission maker). WWR, Amsterdam University Press, e-ISBN 978 90 4851 199 0

TSIOTSOU, R., (2006), The role of perceived product quality and overall satisfaction on purchase intentions. *International Journal of Consumer Studies* Vol. 30, 2, pp 207–217.

VINK P., IMADA A.S., AND ZINK K.J.,(2008), Defining stakeholder involvement in participatory design processes, *Applied Ergonomics*, Vol. 39, pp 519–526.

VOSKAMP, P. (2008), *Basisboek ergonomie*, (Basic book: ergonomics) Groningen/houten, Wolters-Noordhoff,NL.

WEVER, R., VAN KUIJK J., AND BOKS, C;, (2008), User-centred Design for sustainable Behaviour. *International Journal of Sustainable Engineering* Vol. 1, 1.

ZEITHAML, V.A., (1988), Consumer Perception of s Price, Quality, and Value: A Means-End Model and Synthesis of Evidence. *Journal of Marketing*, Vol. 52, 3, pp. 2-22.

CHAPTER 6

Essentials in the Design Process for Creating Comfort in Vehicle Seats

REFERENCE PUBLICATION:
Kok, B.N.E., Slegers, K., and Vink, P., (2015), Essentials in the Design Process for Creating Comfort in vehicle Seats. *Applied Ergonomics*. (accepted Feb 2016)

6. Essentials in the Design Process for Creating Comfort in Vehicle Seats

ABSTRACT

There is an increasing interest in automotive comfortable seating. This study, consisted of a survey and a focus group discussion, focussed on the effect of the design process on the comfort of seats. The research goal was 1) identifying which components in the design process professional designers believe contribute to vehicle seating comfort and 2) assess whether these components are implemented in actual design processes. The results show that four main components were considered important for comfort: 1) state of the art analysis, 2) ergonomic and functional study, and 3) user involvement and 4) prototyping. Several positive correlations were found between the scores for the importance of the components and their actual application. Despite high scores for the importance of components 'ergonomic and functional study' and 'user involvement', these were not often applied in actual design processes. A possible explanation for the difference between importance and application is that the professionals do not decide on the design process. Further research is needed to elucidate why the latter components are not often applied.

HIGHLIGHTS

- Focusing on human factors in the design process, especially by performing ergonomic and functional analysis and involving users, is considered important for designing comfortable vehicle seats.
- Professional designers emphasized that, to achieve innovations in vehicle seats, not only users, but also other stakeholders (management, OEM, etc.), should be involved in the design process.
- Only a few significant correlations were found between the perceived importance of specific design process components of vehicle seats and in the actual utilization of those components in the design process.

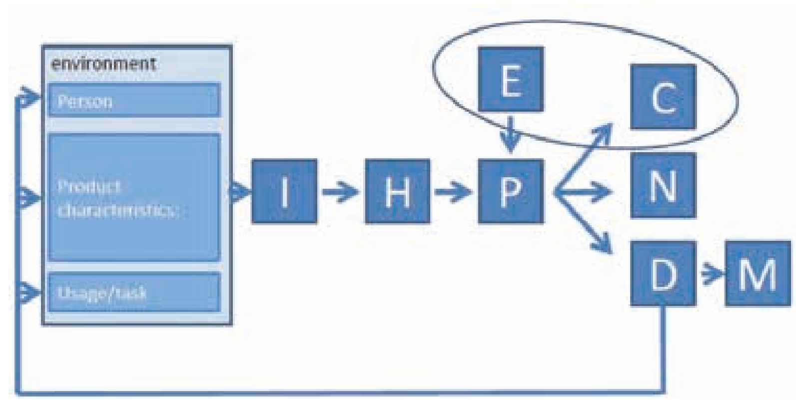
KEYWORDS

Comfort, design process, seating, seat design

6.1 INTRODUCTION

6.1.1 BACKGROUND

Developing comfortable seats is important in the automotive industry (Verver et al., 2005; Fazlollahtabar, 2010). Designing a comfortable seat is a complex process as a seat should support different activities, it should be suitable to a range of human sizes and should facilitate intensive use for many years (Kamp, 2012). Vink and Hallbeck (2012) developed a model to understand the experience of comfort and discomfort by users (see figure 1). According to this model, comfort and discomfort are affected by several elements such as the interaction between the product and the user, the effects of the use of the product on the human body (e.g. blood flow or muscle tension), and the product perception, which is influenced by expectations and first impressions.



I = interaction	C= comfort
H= internal human body effect	N= nothing, neutral
P= perception	D= discomfort
M= musculoskeletal complaints	
E= expectation	

FIGURE 6.1: The comfort model of Vink and Hallbeck (2012)

In the research described in this paper, the effects of several components, in the design processes (i.e. all actions steps methods etc. applied in the design process) of professional vehicle seat designers, on comfort were studied. Objective quality methods seem to be advantageous compared to subjective methods with respect to issues regarding required time, number of subjects and reproducibility and reliability (Looze, Kuijt-Evers and Dieën, 2010). However, as Helander (2003) stated that in the end, the customer will be guided more by aesthetics than longer-term ergonomic factors, because many ergonomics features that are supposed to relieve discomfort in sitting are indistinguishable and people are often not consciously aware of their presence. Obviously there are relationships between discomfort and objective parameters; Looze, Kuijt-Evers and Dieën, (2010) found, in their review of twenty-one studies, relationships between the subjective rating of discomfort and measures of objective parameters. Good pressure distribution appeared to be the objective measure with the most clear association with subjective experience.

Many studies have been done to understand the influence of the design process on the experience of comfort (e.g. Vink and Hallbeck, 2012; Kolich, 2008; Verver et.al., 2005; Vink et.al., 2012). In addition, there is a considerable body of scientific literature on design processes (i.e. Boeijen et al., 2013; Creswell,2003), as well as guidelines and handbooks on design processes (i.e. Roozenburg and Eekels; Eger et al., 2010; Daams, 2011). There is even literature on specific approaches of design processes of seat design, as illustrated in the study of Fai et al. (2007), who describe ten different ways of approaching seat design in their review study and in his book "rethinking sitting" Opsvik (2008) describes how different design approaches have resulted in totally new sitting products including examples that are completely different from classic chairs.

Concerning the design processes there are several papers which specifically addressing design of comfortable seats. Of course a seat for a Bentley has a more complex process (Godot, 2016) than a seat that was not adaptable and used in a train (Bronkhorst et al., 2005).

Franz et al. (2011) describe a light weight car seat design based on the shape of the human body. This design process starts with an analysis phase in which the car type and type of user are determined, but also more specific data are gathered concerning the ideal angles of seat and back rest. These were determined based on literature. The roofline, the pedals and steering wheel position were given by the department determining the styling of the outside of the car. By placing subjects in a vacuum mattress placed on a wooden seat frame with the literature based angles the contour of the human body was determined using p5-p95 participants. Based on this contour and existing data on ideal pressure distribution a seat was shaped in the generation phase and tested again (evaluation phase). Based on the test the seat was optimized and detailed styling was made in line with the exterior. Also, this seat was again tested with subjects, but also on many mechanical aspects and with respect to norms and guidelines. The implementation phase was done by the marketing department. Other papers show a likewise approach (e.g. Andersen and Wallin, 2007; Hartung, 2005; Silva et al., 2012; Smulders et al., 2016; Zenk et al., 2012). However, the contour study was not often done in other design processes (except for the study of Smulders et al. (2016). Bronkhorst et al (2005) followed a likewise process in designing a comfortable passenger seat, which was later done as well by Groenesteijn et al.

(2014). They also, started with analyses, but in this case observed 1700 users. From these observations the four most frequent tasks were selected as well as the essential anthropometrical characteristics. More detailed, measurements were done in the laboratory on postures and comfort for these tasks and these sized participants on existing seats. This was input for the first design (generation phase). This new designed seat was tested (evaluation phase) and adapted again based on the test and then the seat was manufactured and implemented. Also, Jung et al. (1998) followed these steps in a passenger seat design process: A survey and analysis of design requirement was first conducted. This was the base for designing the passenger seats. Prototypes were made and evaluated and implemented in the seat arrangement and coach layout. The studies in these papers focussed on the effects of the physical characteristics of seats on the perception of comfort.

However, little is known about the complete design process of seating products: what actually happens during the design process and which actions, tools and methods in the design process are of importance to enhance comfort in seating products? These actions, tools and methods in the design process will be referred to as design process components.
The design process components that were included in the present study are based on a previous study (Kok et al., 2015) and can be categorized as follows:

- *'State of the art'*: the mapping of existing related and non-related products (with similar functionality) by means of technology, science (including social science) and material research
- *'Design shaping methods'*: the use of sketching techniques, computer rendering, 3D models and/or working models
- *'Ergonomic and functional study'*: the use of ergonomic guidelines, analysis of the product's functions and the user's tasks, analysis of the risks and mistakes that users might make while using the product, testing of similar products by the designer, testing of the design itself by the designer, etc.
- *'User involvement'*: efforts to involve users in the design process, e.g. by observation, questioning, or user tests.
- *'Design research tools'*: the use of tools such as card sorting, personas, etc.

For the study, the four phases of the design process proposed by Howards et al. (2008) were used: 1) the analysis phase in which information is gathered considering users, materials, technology etc.; 2) the generation phase in which concepts, design strategies, etc. are generated; 3) the evaluation phase in which models, implemented technologies, prototypes, etc. are evaluated; and 4) the communication/implementation phase in which the final product is introduced to the client or customer.

6.1.2 AIMS

The study described in this paper aimed to identify which design process components professional designers consider to be important for designing comfortable vehicle seating products. In addition, the goal was to assess whether these designers actually implement these components in their own design processes.

6.2 HYPOTHESES

The following categories were expected to be considered as important for creating comfortable seats: 'state of the art', 'ergonomic and functional study' and 'user involvement'. Regarding the first category, the model of Vink and Hallbeck (2012) states that users' expectations influence the perception of comfort. Since expectations are partly based on products that are already familiar to the user (Vink and Hallbeck (2012), it was hypothesized that designers consider design process components in the category 'state of the art' study, (for example research about comfortable surface materials), especially important. Secondly, the importance of doing ergonomics research for designing comfortable seats has been indicated frequently in literature. For instance, Zenk, (2012) showed that the form of the seat pan is a decisive factor for comfort, as it affects the pressure distribution between buttock and back of the user on the one hand and the seat on the other hand. Franz et al. (2011) showed that seats that follows the human body contour are considerably more comfortable. As a result, it was hypothesized that designers value the importance of design process components in the category 'ergonomic and functional study' during the seat design process. Finally, as comfort is a subjective experience (Vink et.al., 2012) and can only be evaluated by the users themselves, design process components related to the category of 'user involvement' were hypothesized to be considered an essential part of the design process as well. This is backed up by research that showed positive effects of user participation on product experience (e.g. Vink et al., 2008; Kujala, 2003). Concerning the actual utilization of the design process components, it is expected that the components that designers consider to be important are applied more frequently than other components.

6.3 METHODS

To gather information on the design process regarding comfortable vehicle seats in reality a focus group study was used. Additionally, participants completed a survey in which they indicated the activities during the design process and what components in the design process they consider to be important to create comfort.

6.3.1 SUBJECTS

This study consisted of a survey and a focus group discussion. The survey and focus group discussion were conducted during a workshop on measuring and improving comfort at the International Conference Innovative Seating 2014 in Düsseldorf, Germany. 19 professionals participated in the workshop. All of them had at least 5 years of experience in seat design. More specifically, the participants in this study were involved in the design process of vehicle seats or parts of vehicle seats (for example seat ventilation). Most of the workshop participants were engineers. The other professionals were ergonomists, designers, managers and sales managers (see Table 6.1).

Table 6.1: Professional background of the participants

PARTICIPANTS FUNCTION	N
Ergonomist	3
Engineer	7
Designer	3
Managers	3
Sales manager	3

6.3.2 SURVEY

The participants were asked to fill in the survey based on their most recently completed seat design process of an entire seat, these were al processes in which a seat was re-designed. The survey consisted of three parts. Part one addressed job function and education and a short description of the most recent design project was asked. Parts two and three were about the recent design process participants had described in part one. In part two, for that specific design process, the participants were asked to rate the importance for comfort of each individual design process component on a 10-point Likert scale (see Table 6.2). In the last part of the survey, the participants had to indicate for each component whether they had executed it themselves in their recent design process (yes/no). To assess how thorough these design process components were applied, the participants were asked whether these design process components were applied thoroughly or cursorily. Because different design processes might be more relevant in different design phases the participants had to indicate in which phase of the design process this happened (analysis, generation, evaluation, communication/ implementation). The questions of part three of the survey are shown in Table 6.3.

Table 6.2: survey part three: importance of design process components for comfort

IMPORTANCE IN THE DESIGN
PROCESS OF THIS PARTICULAR PROJECT

mark with 'x' the importance of each design process component for comfort

1 = **not** important at all

10 = extremely **important**

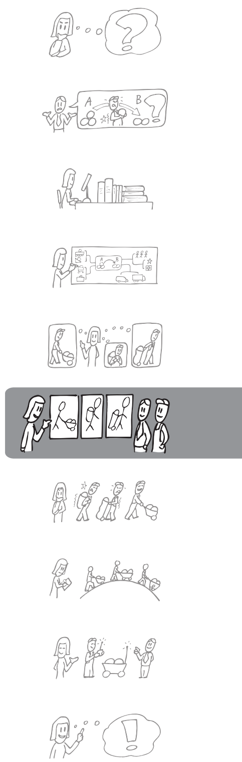
DESIGN PROCESS COMPONENTS (DCP)	IMPORTANCE OF THE DCP FOR COMFORT									
	1	2	3	4	5	6	7	8	9	10
STATE OF THE ART										
state of the art of similar products										
state of the art of non-relating products (with properties which might be useful for your design)										
technology, materials etc research										
DESIGN SHAPING METHODS										
designing by sketching										
designing by computer rendering (CAD...)										
designing by making tangible models (3D)										
designing by making working models										
ERGONOMIC & FUNCTIONAL STUDY										
consulting ergonomic guidelines										
product function risk and mistake analysis (based on info consumer websites, research literature)										
product function risk and mistake analysis by testing and using the products yourself										
product function risk and mistake analysis of the designed product										
USERS INVOLVEMENT (UI)										
questioning users										
observation										
feedback on concepts and/or models										
feedback on concepts (2D)										
feedback on models (3D)										
feedback on working models										
DESIGN RESEARCH TOOLS										
Brainstorming										
Card Sorting										
Checklist Review										
Context Mapping										
Customer Journey Map										
Diary										
Focus Groups										
Mapping										
Personas										
Prototyping										
Scenarios										
Shadowing										
other:										

Table 6.3: survey part two: application of design process components

DESIGN PROCESS COMPONENTS AND COMFORT

mark with 'x' for each component you applied during the design process

COMPONENT IN THE DESIGN PROCESS	IN PHASE						
	CURSORILY	THOROUGHLY		ANALISIS PHASE	GENERATION PHASE	EVALUATION PHASE	COMMUNICATION / IMPLEMENTATION
STATE OF THE ART							
state of the art of similar products							
state of the art of non-relating products (with properties which might be useful for your design)							
technology, materials etc research							
DESIGN SHAPING METHODS							
designing by sketching							
designing by computer rendering (CAD...)							
designing by making tangible models (3D)							
designing by making working models							
ERGONOMIC & FUNCTIONAL STUDY							
consulting ergonomic guidelines							
product function risk and mistake analysis (based on info consumer websites, research literature)							
product function risk and mistake analysis by testing and using the products yourself							
product function risk and mistake analysis of the designed product							
USERS INVOLVEMENT (UI)							
questioning users							
observation							
feedback on concepts and/or models							
feedback on concepts (2D)							
feedback on models (3D)							
feedback on working models							
DESIGN RESEARCH TOOLS							
Brainstorming							
Card Sorting							
Checklist Review							
Context Mapping							
Customer Journey Map							
Diary							
Focus Groups							
Mapping							
Personas							
Prototyping							
Scenarios							
Shadowing							
other:							



6.3.3 FOCUS GROUP

In the focus group discussion, which was held after completing the survey, the relationship between the design process and comfort in seat design was discussed. As such, the survey also aimed to sensitize the participants for the focus group discussion. Three main questions (see box 1) were formulated and each question was discussed to reach consensus for a conclusion, which was summarized on a flip chart. The focus group was moderated by the first author and notes were taken by the third author. The notes taken during the focus group were used to elucidate the results of the survey.

> **BOX 6.1.**
> **QUESTIONS IN THE FOCUS GROUP:**
>
> • Which design components are important to create comfort in seating products?
>   o Why?
>   o What are /might be the reasons to not (thoroughly) apply certain components which you find important for comfort in the design process?
>
> • Which phases of the design process are the most important for comfort in seating products?
>
> • What are the facilitators, constraints and pitfalls in the design process of comfortable seats?
>   o What changes are needed to avoid these constraints in the design process?

6.3.4 ANALYSIS

The survey data were analysed with SPSS Statistics 21. Before analysing the importance, ratings of the components in the design processes, the actual application of the components, and the possible correlations between them, possible effects of the background of the professionals on the results were studied. For this purpose, Freidman non parametric K-sample tests were done to assess whether any of the different background variables of the professionals influenced either the importance of the components for comfort as well as the application of each component. The score of importance was collected by means of a Likert score. Because the average score per components were higher than four, only the components which received a score higher than the mean (6.6) were considered. In order to study how thoroughly each component was applied by the participants, the answers were coded as follows: if the participant indicated 'cursorily' a score of 1 was given

in SPSS whereas for indicating 'thoroughly', a score of 2 was assigned. The correlation between the importance for comfort (scored by the professionals) and the application of the components was analysed by crosstabs ($\alpha < 0.05$, double edged[12]).

6.4 RESULTS AND DISCUSSION: THE SURVEY

In this section, the reported importance of the design process components and the positioning of the components in the design process is described based on the survey. Whether the different background of the professionals influenced either the importance of the components for comfort or the application of each component was analysed and no significant differences were found, therefore all participants were considered as one homogeneous group.

6.4.1 THE IMPORTANCE OF THE COMPONENTS FOR COMFORT

The scores of the importance for each component are listed in Table 6.4. The mean rating (of all components) was 6.6/10. The components in the category 'ergonomic and functional study' had the highest overall scores. In that category, the individual components received average scores between 7 and 9/10, among which the highest scores were given for 'functional, risk and mistake analysis of the designed product' (8.8/10) and 'functional, risk and mistake analysis by self-testing'(8.4/10). In the category 'user involvement', the average scores of three components were higher than the mean score. Those components were 'questioning users' (7.9/10), 'observation' (6.9/10) and 'feedback on working models'(6.8/10). In the category 'design research tools' four components received average scores above the mean score, with the highest being 'prototyping' (9.0/10), followed by 'focus group' (8.08/10), 'customer journey map' (7.4/10) and 'check list review' (7.3/10). In the categories 'state of the art', only 'state of the art of similar products' received a score higher than the average score (7.1/10). In the category 'design shaping methods' also one component received a score higher than the mean score: 'designing by making working models' (7.6/10).

11. Crosstabs are used to analyse hypotheses about how some variables are contingent upon others. Crosstabs are use if the variables level is nominal or ordinal, (Dalen and Leede, 2009), which is the case in this study. The crosstab analyses were performed double edged.

Table 6.4: Perceived importance of the components for comfort

COMPONENTS	MEAN SCORE	STD. DEVIATION	MISSING
STATE OF THE ART			
state of the art of similar products	7.1	2.0	2
state of the art of non-relating products	5.8	1.8	2
technology, materials etc research	6.6	1.8	2
DESIGN SHAPING METHODS			
designing by sketching or rendering	5.4	3.1	4
designing by making tangible models (3D)	6.3	3.0	3
designing by making working models	7.6	2.7	3
ERGONOMIC & FUNCTIONAL STUDY			
consulting ergonomic guidelines	7.3	1.7	3
product function risk and mistake analysis	7.9	1.4	4
product function risk and mistake analysis by self-testing	8.4	1.7	4
product function risk and mistake analysis developed product	8.8	1.7	4
USERS INVOLVEMENT (UI)			
questioning users	7.9	2.4	3
observation	6.9	1.9	3
feedback on concepts and/or models			
feedback on concepts (2D)	4.4	2.3	4
feedback on models (3D)	4.9	2.7	4
feedback on working models	6.8	2.0	4
DESIGN RESEARCH TOOLS			
Brainstorming	6.3	2.9	6
Card Sorting	4.2	2.0	7
Checklist Review	7.3	1.9	5
Context Mapping	5.7	2.1	9
Customer Journey Map	7.4	1.8	7
Diary	5.3	2.5	8
Focus Groups	8.0	1.8	6
Mapping	6.0	1.8	8
Personas	4.4	2.5	7
Prototyping	9.0	1.7	4
Scenarios	5.8	1.7	8
Shadowing	5.5	3.3	8
other: (3D virtual simulation)	7.0	0.0	18
MEAN SCORE (ALL COMPONENTS TOGETHER): 6.6			

6.4.2 FREQUENCY OF APPLICATION OF DESIGN PROCESS COMPONENTS

Most components were applied either cursorily or thoroughly by 3/5 or more of the participants (see table 6.5). The reported application (cursorily and thoroughly) of the components was high in the category 'ergonomic and functional study' and 'design shaping methods' the components were applied in at least 79% of the processes. The frequency of the components that were applied thoroughly, was lower. Only one component, 'functional, risk and mistake analysis of the designed product' was applied thoroughly by more than 50% of the participants. The components in the category 'user involvement' were applied (cursorily or thoroughly) 58% to 79% of the design processes. Less than half of the participants indicated that they had applied 'user involvement' thoroughly.

Within the category 'design research tools' the largest variation was found in the utilization of the individual components, ranging from 0 to 83%. Prototyping was applied thoroughly by the largest number of participants (79%). This category also had the most items, which may have increased the chance that more variation is shown within the category.

The most frequent applied components were found in the category 'design shaping methods' for both cursorily or thorough application (79% - 89%) and thorough application (53% - 63%), (see Table 6.5).

Table 6.5: Application of the components in the design rpocess in general

COMPONENTS	CURSORILY		THOROUGHLY		TOTAL (C+T)		MISSING
STATE OF THE ART							
state of the art of similar products	5	(26%)	10	(53%)	15	(79%)	0
state of the art of non-relating products	8	(42%)	5	(26%)	13	(68%)	0
technology, materials etc research	6	(32%)	8	(42%)	14	(74%)	0
DESIGN SHAPING METHODS							
designing by sketching or rendering	5	(26%)	12	(63%)	17	(89%)	1
designing by making tangible models (3D)	5	(26%)	10	(53%)	15	(79%)	1
designing by making working models	4	(21%)	13	(68%)	17	(89%)	1
ERGONOMIC & FUNCTIONAL STUDY							
consulting ergonomic guidelines	11	(58%)	6	(32%)	17	(89%)	0
product function risk and mistake analysis	6	(32%)	9	(47%)	15	(79%)	0
product function risk and mistake analysis by self-testing	10	(53%)	7	(37%)	17	(89%)	0
product function risk and mistake analysis developed product	6	(32%)	11	(58%)	17	(89%)	0
USERS INVOLVEMENT (UI)							
questioning users	11	(58%)	4	(21%)	15	(79%)	0
observation	9	(47%)	6	(32%)	15	(79%)	0
feedback on concepts and/or models							
feedback on concepts (2D)	8	(42%)	3	(16%)	11	(58%)	2
feedback on models (3D)	7	(37%)	5	(26%)	12	(65%)	2
feedback on working models	6	(32%)	8	(42%)	14	(74%)	2
DESIGN RESEARCH TOOLS							
Brainstorming	4	(21%)	12	(63%)	16	(83%)	0
Card Sorting	6	(32%)	2	(11%)	8	(42%)	2
Checklist Review	3	(16%)	11	(58%)	14	(74%)	1
Context Mapping	7	(37%)	0	0	7	(37%)	1
Customer Journey Map	6	(32%)	3	(16%)	9	(47%)	1
Diary	5	(26%)	2	(11%)	7	(37%)	1
Focus Groups	5	(26%)	6	(32%)	11	(58%)	1
Mapping	9	(47%)	1	(5%)	10	(53%)	0
Personas	6	(32%)	1	(5%)	7	(58%)	1
Prototyping	1	(5%)	15	(79%)	16	(83%)	1
Scenarios	6	(32%)	4	(21%)	10	(53%)	2
Shadowing	6	(32%)	1	(5%)	7	(37%)	2
other: (3D virtual simulation)	0	0	0	0	0	0	2
the percentage of participant that applied the components is indicate in parentheses							

Frequency of application of components in the design process per phase

Table 6.6 shows the application of the components in different phases in the design process. In the category 'ergonomic and functional study' the component 'ergonomic guidelines' were consulted the most in the analytic phase (48% of the participants used guidelines in this phase), the other components were applied mostly in the evaluation phase (by 47% of the participants) except for the 'functional, risk and mistake analysis by self-testing, which was applied most in the generation and evaluation phase (79%). The components in the category 'user involvement' were applied mostly in the 'evaluation phase', except for the component 'feedback on 2D and 3D models' and 'observation'. In the category 'design research tools', the component

'prototyping' was applied the most in the generation phase, 'brainstorming' was done frequently in the analysis phase and 'check list review' in the generation and evaluation phase. In the communication/implementation phase the components of all categories were applied in 1/5 or less of the design processes.

Table 6.6: Application of the components in the design process per phase

COMPONENTS	ANALYSIS PAHSE		GENERATION PHSE		EVALUATION PHASE		COMMUNICATION/IMPLEMENTATION		MISSING	
STATE OF THE ART										
state of the art of similar products	15	(78%)	5	(26%)	13	(68%)	4	(21%)	0	
state of the art of non-relating products	7	(37%)	4	(21%)	1	(5%)	3	(16%)	4	(21%)
technology, materials etc research	9	(48%)	3	(16%)	3	(16%)	3	(16%)	4	(21%)
DESIGN SHAPING METHODS										
designing by sketching or rendering	10	(53%)	11	(58%)	4	(21%)	4	(21%)	4	(21%)
designing by making tangible models (3D)	6	(29%)	11	(58%)	5	(26%)	4	(21%)	4	(21%)
designing by making working models	7	(37%)	13	(64%)	7	(37%)	4	(21%)	4	(21%)
ERGONOMIC & FUNCTIONAL STUDY										
consulting ergonomic guidelines	9	(48%)	6	(32%)	5	(26%)	1	(5%)	5	(26%)
product function risk and mistake analysis	7	(37%)	15	(79%)	15	(79%)	3	(16%)	4	(21%)
product function risk and mistake analysis by self-testing	6	(29%)	3	(16%)	9	(47%)	5	(26%)	5	(26%)
product function risk and mistake analysis developed product	3	(16%)	5	(26%)	9	(47%)	6	(32%)	4	(21%)
USERS INVOLVEMENT (UI)										
questioning users	9	(48%)	1	(5%)	8	(42%)	3	(16%)	5	(26%)
observation	6	(32%)	2	(11%)	6	(32%)	2	(11%)	6	(32%)
feedback on concepts and/or models										
feedback on concepts (2D)	5	(26%)	0		0		0		8	(42%)
feedback on models (3D)	4	(21%)	4	(21%)	2	(11%)	0		7	(37%)
feedback on working models	4	(21%)	5	(26%)	7	(37%)	1	(5%)	7	(37%
DESIGN RESEARCH TOOLS										
Brainstorming	11	(58%)	5	(26%)	1	(5%)	0		4	(21%)
Card Sorting	3	(16%)	3	(16%)	1	(5%)	0		6	(32%)
Checklist Review	5	(26%)	7	(37%)	7	(37%)	2	(11%)	3	(16%)
Context Mapping	4	(21%)	1	(5%)	0		1	(5%)	3	(16%)
Customer Journey Map	5	(26%)	2	(11%)	2	(11%)	1	(5%)	3	(16%)
Diary	1	(5%)	2	(11%)	1	(5%)	1	(5%)	8	(42%)
Focus Groups	3	(16%)	2	(11%)	5	(26%)	0		5	(26%)
Mapping	2	(11%)	1	(5%)	1	(5%)	1	(5%)	6	(32%)
Personas	2	(11%)	1	(5%)	0		0		6	(32%)
Prototyping	6	(32%)	12	(63%)	4	(21%)	2	(11%)	5	(26%)
Scenarios	6	(32%)	2	(11%)	3	(16%)	0		7	(37%)
Shadowing	1	(5%)	1	(5%)	3	(16%)	0		6	(32%)
other: (3D virtual simulation)	0		0		0		0	0	6	(32%)
the percentage of participant that applied the components is indicate in parentheses										

Correlations between the perceived importance of the design process components and its application

Significant between the importance of the design process component and the application of the design process component were only found for four out of 28 components: ‘State of the art of similar products’, ‘Designing by making working models’, ‘function, risk, and mistake analysis of the designed product’ and ‘Prototyping’. The correlations are indicated in Table 6.7.

Table 6.7: Correlations between the perceived importance and in practice used components in the design process

COMPONENTS IN THE DESIGN PROCESS	SPEARMAN CORRELATION	p
State of the art		
State of the art of similar products	0.716	0.014*
State of the art of non-relating products	-0.599	0.054
Technology, science, materials etc research	-0.304	0.405
Prototyping	0.868	0.014
Design shaping methods		
designing by sketching or rendering	-0.613	0.125
designing by making tangible models (3D)	-0.177	0.703
designing by making working models	0.914	0.002*
Ergonomic & functional study		
consulting ergonomic guidelines	0.408	0.348
product function risk and mistake analysis	0.626	0.143
function risk and mistake analysis by self-testing	0.513	0.214
function risk and mistake analysis developed	0.803	0.018*
User involvement (UI)		
questioning users	0.554	0.383
observation	0.664	0.060
feedback on concepts and/or models		
feedback on concepts (2D)	0.813	0.051
feedback on models (3D)	0.680	0.105
feedback on working models	0.000	1.000
Design research tools*		
brainstorming	0.748	0.167
card sorting	0.811	0.133
checklist review	0.520	0.429
context mapping	0.866	0.667
customer journey map	-0.351	0.600
diary	0.400	0.625
focus groups	0.188	0.750
mapping	0.894	0.333
personas	0.444	0.500
prototyping	0.868	0.014*
scenarios	0.316	1.000
shadowing	0.333	0.833
other: (3D virtual simulation)*	/	/

α =0.05
* only one participant gave score for this DPC

6.5 RESULTS AND DISCUSSION: LINK TO FOCUS GROUP RESULTS

In this section the importance of the components in the design process for creating comfortable vehicle seats is discussed. The results from the focus group are used in this section to elucidate or discuss the results of the survey.

6.5.1 ERGONOMIC AND FUNCTIONAL ANALYSIS

Within the category ‘ergonomic and functional study’ the highest scores of importance for creating comfort, were found for the components ‘functional, risk and mistake analysis of the designed product’ and ‘functional, risk and mistake analysis by self-testing’. These received both an average score for the importance higher than 8/10 (see Table 6.4). This supports our hypothesis that the components of this category would receive a high score of perceived importance for creating comfort in seats. This can be explained because the components in this category enable designers to improve the seat functionality and the human body support of the vehicle seat. Other studies have also shown that by applying ergonomic principles and creating a good body support seats can be created which results in experiencing comfort (e.g. Franz, 2011).

6.5.2 DESIGN RESEARCH TOOLS

The components in the category ‘design research tools’ showed the highest variety in scores and had the highest number of missing values. Four components in this category received an average score higher than the mean score of all components (6.6/10). The component ‘prototyping’ had the highest average score (9/10). The other components that received a score higher than the average were the components ‘focus group’, ‘customer journey map’ and ‘check list review’. In the focus group ‘prototyping’ was also considered by the participants as the most important component in the design process. This was explained by the fact that in designing a seat for a vehicle, the smallest detail can affect the comfort of the product. For example, if the seat surface does not follow the body contour the seat can be perceived as uncomfortable. The use of prototypes can explore the effect of the design on comfort by user testing. Attention to details is also important because the space in which the seat needs to be integrated is limited and small changes (for example a few cm more leg space) can make big difference in the comfort experience (Kremser et al., 2012). Therefore the creation of detailed prototypes is essential for creating comfortable seats, which was also mentioned in the focus group. Another possible explanation is that designers tend to use design research tools that they are familiar with, probably because those tools proved to be successful in the past. The participants mentioned that prototyping is used often, because this provides a lot of useful information.

In the focus group it was brought up that prototyping is very important to test the usability as well as the comfort of the seat. This is in line with other research (Baber and Mirza, 1988; Stanton and Young, 1998) that suggested that professionals tend to restrict themselves to two or three of their favourite methods.

6.5.3 USER AND STAKE HOLDER INVOLVEMENT

The components in the category 'user involvement' were expected to be considered as important. This was true for three of the components: 'questioning users', 'observation' and 'feedback on working models' (see Table 6.4). The participants mentioned that details can cause a product to be comfortable or dis-comfortable and the user is the one who experiences whether or not it is comfortable. This could explain why the other components in this category ('feedback on concepts' and 'static 3D models') were considered to be less important. Because '2D models' and 'static 3D models' don't show as much details to the users as 'working 3D models' and are therefore less interesting to use.
In the focus group, participants indicated that user involvement is important for innovation because of the subjective nature of comfort. An artefact in itself can never be comfortable, it becomes comfortable or not when it is used (Looze et al. 2003). In order to gain insight about the product characteristics that contribute to comfort, users should be involved in the design process and their unique insight into her/his task, work or activity should be explored (Vink, 2006; Vink & Hallbeck, 2012; Groenesteijn et al., 2009). Nonetheless, the professionals in our study also stressed the risk of restricting the innovation in the design process by involving users because users prefer known solutions rather than (extreme new) innovations. This is in line with what De Rijk (2014) stated, there is a tension between the desire of people for traditional products and the need for innovation.
Bakker et al. (2013), discussed another possible bias caused by involving users in the design process due to the risk that users give socially desirable answers. This could be avoided by not (only) asking whether the seat is 'more' comfortable but by questioning users more specifically, like asking for the softness of the back support and adding objective measurements such as pressure distribution recordings etc.
The participants also emphasized in the focus group that next to user involvement, it is important to involve other stakeholders such as upper-management and representatives of the OEMs (Original Equipment Manufacturers). The participants explained that if management and OEMs are not involved during the design process, there is a high risk that the decision makers don't realize the benefits of the innovation in the later phases of the process and stop or alter the development. For example, when extra leg space is created by reducing the thickness of the backrest of the front and rear seats, management may decide to increase the trunk space instead of using

the space for more comfort. Another important reason to involve management and OEM was that the main constraint for innovation in comfort is usually caused by financial issues: the management and the OEM have to be convinced of the return on investment of the innovation. This is in line with the argument of Vink et al. (2008) that a strong management support is one of the success factors in the process towards better comfort and productivity.

6.5.4 STATE OF ART ANALYSIS

A high score for the perceived importance for creating comfort was expected for the components in the category 'state of the art' as expectations play an important role in comfort. This was partly confirmed in this study as the component 'state of the art of similar products' received a high score (7/10). Doing a 'state of the art' analysis enables designers to define the current benchmark of their products and to analyse which innovations are new, or which innovations can be implemented in the seating product that is being designed. It also enables designers to get a clear idea about the possible experiences users could have with the products they are (re)designing.
The discussions held in the focus group indicated that material selection is important for creating comfort in seating. The contact area between the user and the product is quite large for seating products, whereby the tactility of materials influences the experience of comfort or discomfort. Experience with previous materials is important input as well as test with subjects for choosing the right material. Although material selection was considered important to create comfortable seats, in the focus group discussion, the component 'state of the art of technology, materials, science etc. research' received an average score of importance.

6.5.5 PHASES IN THE DESIGN PROCESS

Concerning the phases in the design process, the professionals emphasized the importance of an iterative design process and selecting specific methods, tools, analysis, etc. for each phase. Iterative means that the process is not always a linear process and sometimes steps to previous phases are needed. When looking at the importance of the different phases for creating comfortable seats, which was discussed in the focus group, the analysis phase was considered to be the most important phase in the design process by the participants during the focus group. In this phase, 'prototyping' and 'user involvement' are considered the most important components in the design process. 'Ergonomics principles and usability testing' are considered important in the evaluation phase. The participants emphasized that targets for the designed products should be defined and specified in a very early phase. It is important to define in detail the product characteristics, from the beginning to ensure the compatibility of all the different components of the product (for example the car seat has to fit into a future car with specific dimensions).

6.5.6 CORRELATIONS BETWEEN THE SCORE OF IMPORTANCE AND THE APPLICATION OF THE COMPONENTS.

Significant positive correlations were expected between the application of the components and the score of importance for the component. That is, it was expected that the components that designers considered to be important for comfort in seat design would also be the components that the designers would actually apply in their own design processes. However, only four significant correlations were found (see table 6.7).

A possible explanation for the limited correlations between what the professionals consider to be important and what is actually practiced during the design process could be that the professionals do not have 'carte blanche' in the design process and cannot (or only partly) decide how they carry out the design process. Some components can be omitted because of time and money needed to execute the component, which the professionals do not always have to their disposal or can change during the design process. In the focus group discussion it was mentioned that the management and the OEM have to be convinced of the return on investment of the money invested in the design process. Other researchers (e.g. Oijevaar, 2009; Kujala, 2003) found that user involvement in the process is often left out or reduced because it is a costly part of the process (Oijevaar, 2009; Kujala, 2003) that requires time and effort (Kujala, 2003). Another possible explanation is that the designers felt a kind of pressure to give social desirable answers. The idea was to avoid this bias by making the survey anonymous. The correlations were studied only based on the data of the survey, but as later participants would discuss in the focus group meeting this phenomenon could happen. Also, the method of correlation calculation has its shortcomings. If all values are high on one axis correlations could be low as well. Since it is not known why there is little correlation between what designers find important and what designers actually practice during the design process further research is advised.

6.6 CONCLUSION

The aim of this study was to understand which components in the design process of comfortable seating products are considered as important by professional designers and whether these components are actually practiced. The hypothesis that design process components related to 'state of the art', 'ergonomic and functional study' and 'user involvement' would be considered as important to create comfortable products was partly confirmed in this study. Only the components in the category 'ergonomic and functional analysis' and some of the components in the categories 'user involvement' and 'state of the art' received high scores. This study showed that in the design process 'prototyping' and 'ergonomic and functional study' are considered the most important components for creating comfort. The professionals emphasized that next to user involvement, the involvement of other stakeholders (management, OEM, etc.) is also important. This is to assure that later in the design process the innovation will be accepted. Also, financial issues form an important constraint for innovation in comfort: the management and the OEMs have to be convinced of the return on the investment of the innovation. Finally, only a few significant correlations were found between the perceived importance and actual application of components in de the design process, which means that for comfort seating products the theoretically ideal components are not always applied in practice. Further research to elucidate why the components which are considered to be important are not often applied in the design processes.

ACKNOLEGDGEMENTS

The authors would like to thank the professionals who participated in this study for their cooperation and IQPC to provide us with the opportunity to conduct the survey and focus group.

References

BEI, LT. AND CHIAO, Y-C, (2001), An integrated model for the effect of perceived product perceived service quality, and perceived price fairness on consumer satisfaction and loyalty. Journal of consumer Satisfaction, Dissatisfaction and Complaining Behaviour, Vol 14, pp. 125- 140.

ANNA ANDERSSON, A. AND ÅSA WALLIN, Å., (2007), Modularised Passenger Seats. Linköping University, Linköping.

BABER, C. AND MIRZA, M.G., (1988), Ergonomics and the evaluation of consumer products: surveys of evaluation practices, in *Human Factors in Consumer Product Design*, Stanton, N.A., Ed., Taylor & Francis, London.

BAKKER, I., VOORDT , VAN DER, T., VINK, P., BOON, DE, J., (2013), The use of questionnaires in colour research in real-life settings: in search of validity and methodological pitfalls. *Theoretical Issues in Ergonomics Science*, 1-15 .

BRONKHORST, R.E., KRAUSE, F., (2005), Designing comfortable passenger seats. In: *Comfort and design, principles and good practice*, edited by P. Vink, 155–167. Boca Rotan: CRC Press.

BOEIJEN, A., VAN, (RED.), DAALHUIZEN , J, (RED) ET AL., (2013), *Delfts Design Guide*, TU Delft, NL.

CRESWELL, J.W, (2003), Research Design: Qualitative, Quantitative and Mixed Methods Approaches. SAGE Publications, London.

DAAMS, B. (2011) "*Productergonomie: ontwerpen voor nut, gebruik en beleving.*" (product ergonomics design for usefulness, use and experience), Undedisining, NL.

DIRKEN, H. (2006) *Productergonomie: ontwerpen voor gebruikers*, (product ergonommics: designing for users) Delft, NL, VSSD.

EGER, A., BONNEMA, M., LITTERS, E. , AND VOORT, M., VAN DER, (2010), *Productontwerpen.* (Product Design) Den Haag, Netherlands, Lemma.

FAI, T.C., DELBRESSINE, F. AND RAUTERBERG, M. (2007), Vehicle Seat Design: State of the art and recent development. In: AS. Mokhtar, EJ. Abdullah, NM Adam, AR. Abu Talib, NA. Abdul Jalil, R. Zahari, WMI. Hassan & ZA. Zulkefli (Eds.), *Proceedings World Engineering Congress 2007* (pp. 51-61), Penang Malaysia.

FRANZ, M., KAMP, I. DURT, A., KILINCSOY, U., BUBB, H., VINK, P., (2011), A light weight car seat shaped by human body contour. *Int. J. Human Factors Modelling and Simulation*, Vol. 2, 4, pp. 314-326.

FAZLOLLAHTABAR, H., (2010), A subjective framework for seat comfort based on a heuristic multi criteria decision making technique and anthropometry. *Applied Ergonomics*, vol. 42 , pp 16-28, doi:10.1016/j.apergo.2010.04.00.

FRANZ, M. (2010). Comfort, experience, physiology, and car seat innovation. PhD thesis, Technical University, Delft, the Netherlands.

FRANZ M, KAMP I, DURT A, KILINCSOY U, BUBB H, AND VINK P. (2011) A light weight car seat shaped by human body contour. *Int. J. Human Factors Modelling and Simulation, Vol. 2*, No. 4, 314-326.

GODOT, M., (2016) Bentley motors interior – light weight versus luxury, presentation at the *Automotive Lightweight Interiors Summit* 27-28th January 2016, Munich, Germany.

GROENESTEIJN, L., HIEMSTRA-VAN MASTRIGT, S., GALLAIS, C., BLOK, M., KUIJT-EVERS, L., VINK, P., 2014. Activities, postures and comfort perception of train passengers as input for train seat design. *Ergonomics*, vol. 57,8, pp.1154-1165.

GROENESTEIJN, L., P. VINK, M. DE LOOZE, AND F. KRAUSE. (2009), Effects of differences in office chair controls, seat and backrest angle design in relation to tasks. *Applied Ergonomics* 40: 362–370.

HARTUNG, J., (2005), Objektivierung des statischen Sitzkomforts auf Fahrzeugsitzen durch die Kontaktkräfte zwischen Mensch und Sitz, unpublished Dissertation, Lehrstuhl für Ergonomie, Technische Universität München.

HELANDER, M.G.,(2003) Forget about ergonomics in chair design? Focus on aesthetics and comfort! *Ergonomics*, Volume 46, Issue 13-14, doi: 10.1080/00140130310001610847

HOWARD, T.J., CULLEY, S.J. DEKONINCK, E., (2008), Describing the creative design process by the integration of engineering design and cognitive psychology literature. *Design studies*, Volume 29, Issue 2, 160–180, doi: 10.1016/j.destud.2008.01.001.

JUNG, E.S., HAN, S.H., JUNG, M. AND CHOE, J., (1998), Coach design for the Korean high-speed train: a systematic approach to passenger seat design and layout. *Applied Ergonomics*, vol. 29, 6, pp.507–519.

KOK, B.N.E, SLEGERS, K., VINK, P., (2015), Components in the design process affecting the perceived product quality. Ergonomics in design submitted july 2015

KOLICH, M., (2008), A conceptual framework proposed to formalize the scientific investigation of automobile seat comfort. *Applied Ergonomics*. 39, 15-27. Doi 10.1016/j.apergo.2007.01.003

KREMSER, F, GUENZKOFER F, SEDLMEIER C, ET AL. (2012), Aircraft seating comfort: the influence of seat pitch on passengers' well-being. *Work 2012.*:4936-42.

KUJALA, S.,(2003), User involvement: A review of the benefits and challenges. *Behaviour & Information Technology* 22 (1): 1-16.

LOOZE, DE, M.P., KUIJT-EVERS, L.F.M., VAN DIEËN, J.H., 2003. Sitting comfort and discomfort and the relationships with objective measures. *Ergonomics* 46, 985–997.

OIJEVAAR, K.J., JOVANOVIC, M. DEN OTTER, A.F.H.J., User Involvement in the Design Process of Multifunctional Buildings. In Wamelink, H., Prins, M. &
Geraerdts, R. (Eds.),(2009), CR09, Changing Roles: New Roles and New Challenges, (pp. 485-495). Delft: University Press, NL.

OPSVIK, P. (2008). *Rethinking Sitting*. Oslo, Norway: Gaidaros Forlag SA.

ROOZENBURG, N. AND EEKELS, J. (1995) *Product Design: Fundamentals and Methods*. Chichester: Wiley.

RIJK, DE, T, *Inaugural: What design can do!* (2014, May8) TU Delft recordings inaugural,{podcast} retrieved from

SILVA, L.DA, BORTOLOTT, S.L.V., MARTINS CAMPOS, I.C., AND DÍAZ MERINOA E.A., (2012), Comfort model for automobile seat. *Work*, vol.41, pp. 295-302.

SMULDERS, M., BERGHMAN, K., KOENRAADS, M., KANE, J.A., KRISHNA, K., CARTER, T.K., SCHULTHEIS, U., (2016), Comfort and pressure distribution in a human contour shaped aircraft seat (developed with 3d scans of the human body). *Work* , in press

STANTON, N.A. AND YOUNG, M. (1998), Is utility in the mind of the beholder? A review of ergonomics methods, *Appl. Ergonomics*, 29, 41–54.

VERVER, M.M, DE RANGE, R., VAN HOOF, J., WISMANS, J/S.H.M., (2005), Aspects of seat modelling for seating comfort analysis. *Applied Ergonomics,* 36, 33-42. Doi: 10.1016/j.apergo.2004.09.002.

VINK, P., BAZLEY, C., KAMP, I., BLOK, M., (2012), Possibilities to improve the aircraft interior comfort experience. *Applied Ergonomics*. 43, 354-359. Doi: 10.1016/j.apergo.2011.06.011

VINK, P., HALLBECK, S., (2012) Editorioal: Comfort and discomfort studies demonstrate the need for a new model., *Applied ergonomic*. 43, 271-276. Doi: 10.1016/j.apergo.2011.06.001.

VINK P., IMADA A.S., ZINK K.J.,(2008) Defining stakeholder involvement in participatory design processes, *Applied Ergonomics* 39, USA, , pp 519–526.

VINK, P. KONINGSVELD, E.A.P., MOLENBROEK J.F., (2006) Positive outcomes of participatory ergonomics in terms of greater and higher productivity., *Applied ergonomics 37*, 537-546. Doi:10.1016./j.apergo.2006.04.012.

ZENK , R., FRANZ, M., BUBB, H., VINK, P. (2012) Technical note: Spine loading in automotive seating. *Applied Ergonomics* 43, 290-295. doi:10.1016/j.apergo.2011.06.004

Discussion Part II

In Part II, the second sub-question "How do individual design process components relate to perceived product quality?" was addressed in Chapter 4 and 5. These studies show that certain components in the design process affect the perceived product quality. Both chapters show that the specific design process components that affect perceived product quality can be different for different products. For instance, the components that affect the perceived product quality of newly designed products are different from those that affect the perceived product quality of re-designed products. Differences were also found when comparing the design process components that affect the perceived product quality of products designed for people with special need or disabilities and products designed for people with no special needs or disabilities.

To further analyse these differences, a study with a larger set of data is needed using more design schools. In addition, it is not unlikely that the design process components that are applied depend on the design goals/problems. For example, if one is designing a medical tool used for surgery, special attention should go to the hygiene of the product. Therefore the component 'state of the art of materials, technology, science' highly likely to be applied. When (re-)designing the interface of a digital coffee machine screen on the other hand, designers will probably do more sketching and rendering to create and analyse user interfaces.

Other factors that were not taken into account in the research described in Part II were the intensity and the quality with which the design process components were applied in the design process. For instance, a high quality risk and mistake analysis that is performed only once during the design process probably may lead to better perceived product quality than several poorly performed risk and mistake analyses throughout the design process. The effect of the intensity and the quality of applying the components were not studied in this research and are an interesting focus for future research.

In Chapter 6, the correlation between the design process components that are seen as important by the designers and the actual application of these components was studied. This study showed that the vision of a designer does have an effect on the design process, but other factors like the opinion of stakeholders (e.g. the upper management and OEM) also play an important role (see 6.5.3). Therefore, design education should pay (more) attention to training designers in how they can demonstrate stakeholders such as (upper-) management and OEM of the value of applying certain design process components, since stakeholders do not always estimate this value.

Although further in-depth research about the design process components and their effect on the perceived product quality is needed, the studies described in Part II yielded some important insights, most importantly the fact that the design process does affect perceived product quality and the fact that the design process components that affect perceived product experience may be different for different type of designs. Based on these results, the following advice can be formulated towards designers and design education: Firstly, in design special attention should go to the design process components that can have a positive effect on the perceived product quality. And secondly, different design goals/problems (i.e. re-designing; designing for people with special needs,…) require different approaches. So design education should train future designers to adapt their design process in function of the design goal/problem.

The research in this thesis is mainly based on student cases. In order to be able to generalise the results to the practice of professional designers, a comparison of the design processes of designer students and professional designers was be conducted. This is described in Part III.

PART III

Design Education versus Real World

Design Education versus Real World

The main goal of this research was to identify which components in the design process contribute to a better-perceived product quality. The goal of this PhD research was to retrieve how design education can contribute to better perceived product quality. In the previous chapters the components in the design process were defined as well as the relationship between perceived product quality and the different components. Ideally, the effect of the design process on the perceived product quality is assessed by users. In reality in design education this is not always possible and it is up to teachers to estimate the perceived product quality. In Chapter 7 the ability of design teachers to estimate the user perception of the product quality is analysed. Chapter 7 is added to find out whether the design processes of students are representative for professionals. This research was largely based on student work. The question is of course whether student work is comparable to the work of experienced designers. To validate the results based on the studies with design students, a comparison between the design processes of professionals and of students was made in Chapter 8. This last chapter describes the comparison of the design processes of students and professionals for a specific product type, seats.

During the research process the term for the 'design process components' has changed; in chapter eight, the term 'components in the design process' is used.

CHAPTER 7

Can Design Teachers evaluate Students' Products from an End-User Point-of-View?

REFERENCE PUBLICATION:
Kok, B., Slegers, K., and Vink, P., (2014) Can design teachers evaluate students' products from an end-user point-of-view? In: *Advances in Social and Organizational Factors 2014*, Ed. P Vink, Published by AHFE Conference © 2014, page 59-67.

7. Can design teacher evaluate students' products from and-user point of view?

ABSTRACT

The purpose of design education is to teach future designers to create products that fulfil the needs, wishes and expectations of the targeted users. Therefore, it seems reasonable that teachers in design education should have knowledge on how users experience products and apply this in the evaluation of design assignments. The question is whether 'teachers are able to estimate the user experience?'. To answer this question the correlation between the assessment of products done by users and by teachers is analysed, by assessing 76 products designed by students. The teachers assessment correlated strongly to the assessment done by a jury of end users, ($\rho = 0.743$, $\alpha < 0.000$), if the products designed for general target groups (i.e. adults between 18 and 65 years of age without special disabilities or very specific problems and needs). However, no correlation was found between the assessment of teachers and a jury of end users of products designed for people with disabilities or very specific problems and needs (such as bed bound hospitalized children).

KEYWORDS
Design Assessment, User Experience, User Involvement, Design Education

7.1 INTRODUCTION

In design education design students are trained to create products that fulfil the needs, wishes and expectations of the targeted end-users. During the education program students are coached and assessed mainly by teachers[13] , sometimes assisted by designers and specialists from companies who are co-operating in the student design projects. It is important that the persons who train designer students have a clear understanding of the needs, wishes and expectations of the target groups and of methods to discover those in order to be able to teach students how to focus on end-users in their design work. A part of such education concerns the evaluation of products and services, designed by students, with the end-user in mind. In order to do so teachers in design education should be able to understand users and to estimate how users experience products. Evaluation in education is widely studied, resulting in handbooks (e.g. Eger, 2010; Daams, 2011; Dirken, 2006) and guidelines on the topic (for example Tuning EU, 2013). However, little is known about whether teachers evaluate products and services the same way as end-user do. A lot of research about evaluation in art and design is done, but it is mainly of a general nature. It describes whether evaluations are summative or formative, (Danvers, 2012) or it indicates that assessment should focus on the student, process and product (Harpe et al., 2009). Design assessment is even described as an artful practice that might be linked to a form of connoisseurship (Orr, 2010).

The goal of this study was to explore the relationship between assessments of design students' products carried out by teachers on the one hand and by end-users on the other hand. The hypothesis in this research was: 'teachers are capable of understanding the end-users, resulting in a positive correlation between the assessments of teachers and the assessments of end-users'. The purpose of design education is to educate designers who can design products which fulfil the needs, wishes and expectations of users. It can be assumed that user experience of a product is important to design education, and as a consequence user experience is supposed to be important in the assessment of products designed by students. Which means teachers should be able to understand users and to estimate how users experience products.

In this study the assessment of 76 student products executed by teachers and a jury of users was analysed. The 76 products are divided into a group of products designed for general target groups (i.e. adults between 18 and 65 years of age without special disabilities or very specific problems and needs) and a group of products designed for people with disabilities or very specific problems and needs.

13. *In Belgium, where this study was conducted, the Art Academies are no Universities yet (but will be integrated into the universities in 2015), so the teachers are not (yet) professors.*

Although the hypothesis of this research is ‘teachers are capable of understanding the end-users’, it can also be assumed that designers and users do not share the same vision on products, especially when it comes to innovation. The long time between the introduction of innovative products and the acceptation of this product by the main potential users suggests that designers see products different than common people do. The time between introduction and acceptation can vary between several years to several decades, or even centuries (Rogers, 1995). For that reason, in addition to the research described above, a cognitive mapping was done with design teachers about the way users and designers look at products and assess them. The mapping can also reveal the design teachers view of users.

7.2 METHODS

7.2.1 DATA SET

In this research 76 products designed by students are studied. The products were designed by 54 students of the ‘Product Design Education’ program of the Media Art & Design-faculty (of the Limburg Catholic University College in Genk, Belgium). Some students made more than one product (see Table 7.1). The products were designed by students who were in either the second or third bachelor year (age of the students at the time of study is typically 18- 23 years) or in one of the master years (age at the time of study is typically 21- 26 years). Most products were made by bachelor students (90%) as shown in Table 7.2.

Table 7.1: Number of cases per designer

	NUMBER	% PRODUCTS
Students who designed one product	36	47
Students who designed two products	15	20
Students who designed three products	2	3
Students who designed four products	1	1

Table 7.2: Participant specifications per design process: gender, study level, number of cases per designer

STUDENT’S GENDER	
Male	51 (67%)
Female	25 (33%)
STUDENT’S LEVEL OF EDUCATION	
1st bachelor year	0
2nd bachelor year	39 (51%)
3rd bachelor year	30 (39%)
1st master year	2 (3%)
2nd master year	5 (7%)

Depending on the assignment, each of the students had to create a working prototype of a product or a concept in form of a mock-up or non-working prototype. In addition, the students had to show how their product worked by a presentation (either in PowerPoint or Prezi). In Figure 1 an example of a concept and a working prototype is shown. Most of the products (56/76) are designed for a more general target group, for adults between 18 and 65 years of age without specific disabilities or very specific problems and needs and for a specific activity (for example photography). Twenty products in this study are products designed for people with specific disabilities or very specific problems and needs (for example a washbasin for hairdressers working with elderly) (see Table 7.3).

Table 7.3: type of assignment assignments, subgroup and expected end result

TYPE OF ASSIGNMENT	END RESULT	NUMBER OF CASES
PRODUCTS DESIGNED FOR GENERAL TARGET GROUP WITHOUT SPECIFIC DISABILITIES OR VERY SPECIFIC PROBLEMS AND NEEDS		
Bachelor assignment		
Bicycle aid for teaching children to ride a bike	working prototype	17
Camera support for making pictures at 2.5 m height	concept model	10
Sitting element	concept model	3
Hand tool re-design	working prototype	4
The ultimate mobile means of communication for blind people	concept model	1
Free assignment bachelor graduation	working prototype	16
Interface redesign	concept model	5
PRODUCTS DESIGNED FOR GENERAL TARGET GROUP WITHOUT SPECIFIC DISABILITIES OR VERY SPECIFIC PROBLEMS AND NEEDS		
Bachelor assignment		
Product for daily life for disabled people	concept model	2
mobile toy cabinet for bed bound hospitalized children	concept model	5
Washbasin for nursing home hairdressers	working prototype	6
MASTER ASSIGNMENTS		
Free assignment; master graduation	working prototype	5
Designers Against aids	working prototype	2

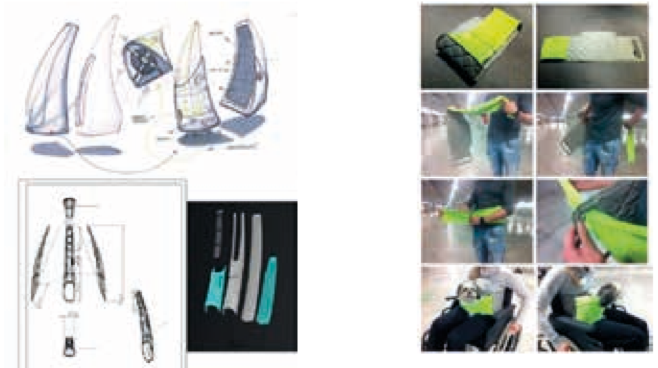


FIGURE 7.1: left: an example of a concept of a new Hairdryer; right: an example of a prototype of a dog support for people in wheelchairs

7.2.2 STUDY DESIGN

7.2.2.1 PRODUCT ASSESSMENT

Both design teachers and a jury of end-users, who were part of the target groups the students designed their products for, assessed the products. This assessment was done after the presentation of the product by the student. In order to ensure that the teachers and the users assessed the same characteristics of the designed products, both groups were asked to pay special attention to: 1) the functionality and usability (i.e. ease of use, adjustability to the user, fulfilment of the users' needs and wishes), 2) the design, (shape colour, texture), and 3) the perceived maintenance of the products. A jury of teachers (3-5 teachers) and a jury of end users (3-10 members) anonymously and individually rated the products by giving a score between 1 and 20 (1=low; 20=high). The jury of users who performed the assessments were not involved in the design process. The teachers were specifically asked only to assess the product, not the design process.

7.2.2.2 STATISTICAL ALALYSIS

The data were analysed statistically, by means of crosstabs[14] ($\alpha < 0.05$, double edged). First the whole group was analysed and afterwards the two subgroups separately.

7.2.2.3 COGNITIVE MAPPING

In order to further understand the similarities and differences between the assessments of teachers and users and to understand the possible differences in the vision on products of designers and users, a cognitive mapping (Martin, 2012) was performed in a workshop at the 18th International Design Educational Meeting (IDEM), 2012. Ten design teachers, from different countries in Europe, South America and the Middle East, participated in this workshop. Two questions were addressed in the mapping: 'Do designers assess products in the same way as users? Why or why not?' The results of the cognitive mapping were summarized in the workshop and approved by the participants.

7.3 RESULTS

7.3.1 COMPARISON OF THE ASSESSMENTS OF THE DESIGN TEACHERS AND END-USERS

The scores for the students' products given by teachers varied between 5 and 17 (scale 1-20), the average score was 11.96 (SD = 2.705). The scores given by the jury of end-users varied between 5 and 18, with an average score of 13.28 (SD = 2.789). Figure 7.2 shows the individual scores for each designed product.

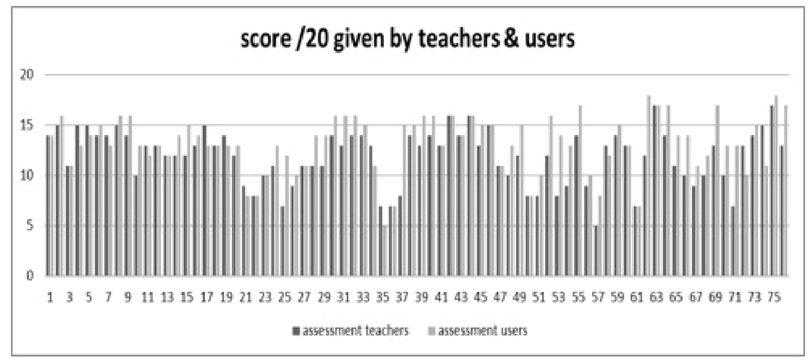


FIGURE 7.2: assessment of the products by design teachers and users

The results of the analysis of the scores for all students' products together showed a strong positive correlation between the assessments of design teachers and of end-users ($\rho = 0.694$, $p < 0.000$; see Table 7.4). Analyses that were performed separately for each of the two subgroups of end-users (i.e. healthy adults and people with disabilities or very specific problems and needs) show different results. No correlation between teachers' scores and users' scores was found for products that were designed for people with disabilities or very specific problems and needs ($\rho = 0.470$, $p = 0.066$). For products that were designed for adults without a disabilities or very specific problems and needs, a strong correlation was again found ($\rho = 0.743$, $p < 0.000$).

14. Crosstabs are used to analyse hypotheses about how some variables are contingent upon others. Crosstabs are use if the variables level is nominal or ordinal, (Dalen and Leede, 2009), which is the case in this study. The crosstab analyses were performed double edged.

Table 7.4: correlations between the assessment of users and teachers

	NUMBER OF CASES	rho	p
All cases	76	0.694	<0.000
Design for people with a disability	20	0.470	0.066
Design for people without specific disability	56	0.743	<0.000
α= 0.05			

7.3.2 DESIGNER TEACHER'S VISION

The results of the cognitive mapping were summarized in the cognitive mapping session workshop and approved by the participants. The main point of view of the designers teachers was: that the difference between designers and users is that users want products that are functional, user friendly, beautiful and familiar to them. New products need to have a relationship to products they already know. All these things are also important to designers, but designers see innovations important as well, much more then (most) users do. Designers (and design teachers) value form, function as well as innovation, while users value mainly form and function, innovation is less important to them. They (users) don't want things that differ much from the products they are used to. Most people don't want modern design or the latest new technologies. They prefer familiar products and products that resemble what they already know. Another conclusion of this workshop was: designing is also about communication. Users don't speak the designers' language, or rather designers don't speak the users' language. Designers don't understand the users (completely). Because of their different approach towards products, designers find different aspects of the product important than the users do. It is difficult to estimate the user experience, especially for young beginning designers. It is only by experience and a lot of user involvement that designers are able to understand the user experience. Young designers often neglect this importance. Design education has the responsibility to increase the awareness of the design students and of the importance of user involvement in design.

7.4 DISCUSSION

The goal of this study was to explore the relationships between the assessment of products by teachers and by end-users. The hypothesis this research was: there is a significant positive correlation between the assessments of teachers and of end-users.

7.4.1 CORRELATIONS BETWEEN TEACHER ASSESSMENT AND USER ASSESSMENT OF PRODUCTS

Although strong correlations, between the assessment done by teachers and the jury of end-users, were found in the analysis of total group of the students' products, it is premature to conclude that teachers are always able to estimate the users experience. When products designed for the more general target group (healthy adults between 18 and 65 years of age, without special disabilities or very specific problems and needs) and products designed for people with disabilities or very specific problems and needs analysed separately, different results were found. For products designed for the more general target group a positive correlation between the assessments by users and by teachers the strong correlation still stands. Apparently, for this subgroup teachers were able to estimate how users would experience the product. This was to be expected since user experience is an important focus of the education and the MAD-faculty and teachers pay a lot of attention to user experience, as mentioned in the introduction. This becomes clear in the many user-oriented courses in the curriculum of Product Design (such as ergonomics, psychology, emotional design, experience design, etc., MAD-faculty, 2013). Moreover, user assessment of products designed by students are organized regularly during the curriculum (in several projects each academy year), enabling the teachers to keep their user knowledge up-to-date.
For products that were designed for people with a disability however, no correlations were found between the assessment of teachers and the jury of end users. A possible explanation for this is that it is simply impossible for a teacher to have in-depth knowledge of the needs of the large variety of specific users their students design for. The lack of correlation between the product assessments of the teachers and of the users emphasizes the importance of involving users in the assessment of products in design education. The goal of design education, as mentioned in the introduction, is to train designers that can create products that fulfil the needs, wishes and expectations of the targeted end-users. Because teachers are unable to fully understand all users it is necessary for student to be confronted with the users assessment of their products. It will make the designer students aware of the designers' limited insight into users and the importance of user involvement in the design process. This is in line with the conclusion of the cognitive mapping with the design teachers were they emphasized the limited understanding of users of young designers and the importance for young designers to be aware of the importance and value of user involvement.

7.4.2 DIFFERENCES IN VISON ON PRODUCTS OF DESIGNERS TEACHERS AND USERS

The cognitive mapping showed that one of the difficulties in designing is communication (in broader sense). Designers don't speak the users language (Kok et al, 2014). Daams (2012) and Dirken (2006) also stated that one of the problems in design is the mismatch between the product image of designers' and users (the product image communicate different to designers than to users). The difference in the designers and users "language" results in products that may be logic and intuitive from the designers' point of view, but not for users. Other researches also showed that designers and users interpret products differently. Van Kuijk (2009) concluded in his research about pre-use and post-use evaluations of electronic consumer products that there is a gap between expected and experienced usability, apparently users don't interpret products the way designers do. Den Ouden (2006) concluded the same in her research: customers have certain expectations of the usability of products they buy. However, once customers use those products, many are not as user friendly as they appear. Products sometimes are so hard to use that consumers need assistance to use them, or even return or abandon the product.

7.4.3 STUDY DESIGN

This study was conducted in a design academy, the products that were assessed here concerned prototypes and concepts and as such often did not focus on secondary use like placing a buggy in the trunk of a car or replacing a battery. Therefore generalization of the findings in this paper should be done with care. It would be interesting to do a similar study on products that are already on the market, to see whether these correlations are still valid. This study was conducted in only one academy, to generalize the correlation between teacher an user assessment more research in other design schools and academies should be conducted. But this study does show the correlation for this specific situation, which is an indication that teacher and user assessment have similarities. Also, in the cognitive mapping in another gremium the relationship was affirmed.

The research itself has also some limitations. The assessments are done individually and anonymously on paper, but it is still possible that the users and teachers are influenced by each other because the products are presented to the users and the teachers at the same time in the same room and they were allowed to ask questions. The juries of end-users were rather small (3-10), especially for the group of products for people with disabilities or very specific problems and needs, nevertheless it gives an indication about how users would assess these products. To draw more general conclusions complementary research with al larger group of end-users should be conducted.

Although the cognitive mapping was done in an international group of designer teachers. Generalizing the designer teachers' vision, about the differences of assessing products between users and designers (teachers), the formulated in the mapping should be done carefully, because the mapping was done in a small group of ten designer teachers. A cognitive mapping with a larger group of designers would be interesting to see whether this vision on the differences in the way people and designers look at products still lasts.

7.5 CONCLUSION

The results show that teachers seem to understand how users (adults between 18 and 65 years of age, without special disabilities or very specific problems and needs) evaluate products. Significant correlations were found between users' evaluations and teachers' evaluations. In the assessment of products for people with disabilities or very specific problems and needs no significant correlation was found between the assessments of users and the assessments of teachers. This may be caused by the fact that it is more difficult for teachers to estimate the user experience for such specific target groups. From this study, we conclude that user involvement in product assessment during design education is important, especially in the assessment of product for people with disabilities or very specific problems and needs.

ACKNOWLEDGEMENTS

The authors would like to thank the students and teachers of Productdesign (MAD-faculty, Genk) and the organization of IDEM for their cooperation. The authors would also like to thank all the persons who did the user assessment.

References

DALEN, J., VAN, AND LEEDE, E., VAN, (2009), *Statistisch onderzoek met SPSS for Windows (statistic research with SPSS for Windows)*, uitgeverij Lemma, NL.

DAAMS, B., (2011), *Productergonomie: ontwerpen voor nut, gebruik en beleving.* (Product Ergonomics: Designing for Usefulness, Use and Perception.) Undedisining, NL.

DANVERS, J., (2012), Qualitative rather than Quantitative: the assessment of arts education. *Networks magazine*, ADM-HEA, http://www.adm.heacademy.ac.uk/resources/publications/networks-magazine/

DIRKEN, H., (1997), *Productergonomie: ontwerpen voor gebruikers.* (product ergonomics: designing for users.), VSSD, Delft, NL.

EGER, A., BONNEMA, M, LITTERS, E. , AND VOORT, M. VAN DER, (2010), *Productontwerpen.* (Product Design) Den Haag, Lemma, NL.

HARPE, B. DE LA, PETERSON J.F, FRANKHAM N., ZEHNER R., NEALE D., MUSGRAVE E., MCDERMOTT R., (2009), Assessment focus in studio: What is most prominent in architecture, art and design? *International Journal of Art & Design Education*, Vol.28, 1, pp. 37-51(15).

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2014), Can Design Teachers evaluate Students' Products from an End-User Point-of-View?, *5th International Conference on Applied Human Factors and Ergonomics AHFE 2014, Kraków, Poland 19-23 July 2014.*

KUIJK, J.I. VAN , (2009) *Managing product Usability: How companies deal with usability in the development of electronic consumer products.* PhD Thesis, TU delft, faculty of industrial design engineering, NL.

MAD-FACULTY, (2013) *Curriculum Productdesign*, retrieved May 2013 from http://www.mad-fac.be/content/productdesign, BE.

MARTIN, B., AND HANINGTON, B., (2012), *Universal methods of design.* Rockport publisher, USA.

ORR, S., (2010), Making Marks: assessment practises in art and design. *Networks magazine*, ADM-HEA, http://www.adm.heacademy.ac.uk/resources/features/making-marks-assessement-practices-in-art-and-design/

OUDEN, E. DEN, (2006), *Development of a design analysis model for consumer complaints: revealing a new class of quality failure.* PhD Thesis, TU Eindhoven, NL.

ROGERS, E.M., (1995), *Diffusion of Innovations*, 4th edition, The Free Press, New York, USA.

TUNING (2013), *Approaches to teaching, learning and assessment in competences based degree programs*, Education and Culture DG, European community, EU.

CHAPTER 8

Are Seat Design Processes of Students Similar to those of Professionals?

REFERENCE PUBLICATION:

Kok, B.N.E., Slegers, K., and Vink, P., (2016), Are seat design processes of students similar to those of professionals? *Work 54(4): 1001-1007*

8. Are seat design processes of students similar to those of professionals?

ABSTRACT

Designers develop their basic competences during their design education and these competences are later amplified and refined based on experience and specialisation during their professional career. Therefore, one could expect that the design processes of professionals and of student designers are conducted in a different way, and that these processes consist of different components (steps, actions, methods, tools, etc. used in the design process). In the research described in this paper, the design processes of seating products of 19 professional designers, 15 master students and 16 bachelor students were compared in order to understand the differences in the components they apply in their design process. The results showed significant differences between professional designers and design students for 53% of the components. The components for which differences were found were applied more frequently by professionals than by students. In addition the effect of the designers experience on the design process is also studied; 40% of the components were found to correlate positively with the amount of experience of the designers.

KEYWORDS

Product development, design process, seating, components in the design process, students versus professionals

8.1 INTRODUCTION

Historically, the aim of design has been to analyse the cultural and social context in order to create progress in the form of everyday experience (Beirne, 2011). To create progress in everyday experience designers need to be able to anticipate the needs, wishes and expectations of users in order to create positive experiences with the products, systems or services they design. How people experience a (physical) product, system or service depends on several factors. The user experience is, for instance, influenced by the physical characteristics of the product and the use of the product, but also by factors such as previous experiences, the user's expectations, preferences, emotions etc. furthermore, product experience differs between people, (Vink and Hallbeck, 2012; Schifferstein and Hekkert, 2008). For example, some people may consider an electric juicer a good product because little force is required to operate it, while people who highly value sustainability might find it a bad product because it consumes more energy (in production and usage) than a manual juicer. Of all these factors, a designer can only affect the product characteristics because these are a direct result of the steps and choices made by the designer and the tools and methods she/he uses in the design process. We will refer to these the steps, choices, tools, methods, etc. as components in the design process, in the remainder of this paper.

In previous research we studied the effects of these components in the design processes of students on the perceived quality of the products they designed. The aim of the current study was to analyse whether the results of our previous studies can be generalised to professional designers. Differences between the design processes of design students and professionals could be expected because of differences in experience and because of the different contexts; compared to students, professionals have a considerable budget, machinery and infrastructure. Also, professionals often work several years to design a new seat, while students can often only work on their designs during a couple of months. Additionally, professionals create products to sell and make profit while design students want to achieve (educational) goals set up by the teachers, (Kok et al., 2015 b). On the other hand, the designers develop their basic competences during their design education and both students and professionals have access to many of the same components in the design process (as shown in Table 8.1) making it likely that similarities between their design processes also exist.

Previous studies have shown differences in the way students and professionals conduct their design process (i.e., Gonçalves et al. 2014; Kujala, 2003). These studies often addressed a specific design phase, (i.e., Gonçalves et al. 2014; Bender and Blessing, 2004), a specific design problem (i.e., Daalhuizen, 2014), or a specific design method (i.e., Kujala, 2003). At a more general level, Gonçalves et al. (2014) compared the sources of inspiration for ideas of students to the sources of inspiration for professionals. They concluded that professionals use 'functional study' more often as a source of inspiration than students do. According to their study, professionals also tend to make more use of prototyping and scenarios to generate ideas than students do. Our previous studies (Kok et al., 2011; Kok et al.; 2015 b) seem to confirm Gonçalves et al.'s finding as we found that students applied a 'functional, risk and mistake analysis by testing themselves' and 'functional, risk and mistake analysis of the designed product' in less than 50% of the cases (Kok et al., 2011) while professionals applied these two components in 89% of the design processes (Kok et al., 2015 b). Similarly, making 3D models was done more often by professionals (89% of the cases, Kok et al. 2015 b) than by students (27%, Kok et al., 2011). These results suggest that there are differences between the design process of students and professionals. Other studies concerning the design processes are available but they often focus on a highly specific part of the design process. Lemons et. al. (2010) for instance, studied the benefits of model building, and Motte and Bjärnemo (2004) researched the cognitive aspects of engineering design activities. In addition, some studies only focus on professional designers or on students, like the study of Pahl et al. (1999), who conducted a résumé of 12 years of interdisciplinary empirical studies of engineering design in Germany. The present study focuses on the design process as a whole by comparing multiple components applied in the design process of design students and professionals in order to determine differences and similarities between the components in the design processes of professionals and design students.

As mentioned earlier, differences can be expected because of the different contexts in which design students and professionals work and because of the differences in experience. The focus of this study was to determine the differences and similarities between the design processes of design students and professional designers. One of the causes of possible differences in the design processes could also be the experience of the designer. The effect of experience on the design processes is also studied.

The exact components, that were used in this study, were based on the components that were identified in earlier studies (Kok et al., 2011; .Kok et al., 2013; Kok et al., 2015 a). The components used in this study were categorised as follows:

- 'State of the art': A mapping of existing related and non-related products (with similar functionality): How did the designer conduct technological, scientific (including social science) and material research?
- 'Design shaping methods': The use of sketching techniques, computer rendering, 3D prototypes and/or working models.
- 'Ergonomic and functional study': The study of ergonomic guidelines and functionality and usability of similar products and/or the designed product
- 'User involvement': The involvement of potential end-users in the design process, e.g. by observation, questioning or user tests.
- 'Design research tools': The use of design tools such as card sorting, proto typing, focus groups, etc.

The individual components of each category are shown in Table 8.1.

Table 8.1: Categories of components in the design process

STATE OF THE ART
state of the art of similar products
state of the art of non-relating products
technology, science, materials etc. research
DESIGN SHAPING METHODS
designing by sketching or rendering
designing by making tangible models (3D)
designing by making working models
ERGONOMIC & FUNCTIONAL STUDY
consulting ergonomic guidelines
product function risk and mistake analysis
function risk and mistake analysis by self-testing
function risk and mistake analysis of the designed product
USERS INVOLVEMENT (UI)
questioning users
Observation
feedback on concepts and/or models
feedback on concepts (2D)
feedback on models (3D)
feedback on working models

In previous research (Kok et al., 2013, Kok et al. 2015 a), these categories explained above were used to study the effect of the components in the design process on perceived product quality. An analysis of 62 design processes of design students showed that applying components in the categories 'ergonomic and functional study', 'user involvement' and 'design research tools' had a significant and positive effect on perceived product quality. Since the previous studies have focused on students' design processes, it is yet unclear whether these findings also apply to professional designers.

8.2 METHODS

8.2.1 SUBJECTS

This study is situated in a specific domain of product design: seat design. Data were collected within the framework of a previous study that dealt with the essentials in the design process for creating comfort (Kok et al., 2015 a). In this previous study, a survey was conducted during a workshop with professional designers who attended the international conference Innovative Seating 2014 in Germany. Nineteen professionals participated in the workshop, all of whom had been involved in the design of seats. The participants were engineers (37%), ergonomists (16%), designers (16%), managers (16%) and sales managers (11%).
The same survey was administered with design students, (who designed a seat): 16 bachelor students, (average age 21 years) and 15 master students (average age 23 years). The bachelor and master students were recruited from the Product Design Education of the Media Arts and Design Faculty (University College Leuven Limburg, Belgium).

8.2.2 SURVEY

The survey consisted of two parts. One part concerned general information about the participant, the other part contained questions about a specific design process of a seating product. For each of the components of the design process described above, the participants had to indicate (mark with an "x") whether they applied the component in this particular design process. The duration of the design process and the experience of the participants were also questioned in this part of the survey.
The bachelor and master students completed the survey on paper after their design assignment was finished and they had received the assessment. The data of the professionals were collected by a survey on paper which they completed during a workshop.

8.2.3 ANALYSIS

The data were analysed with SPSS Statistics 21. Components that had been applied by participants were given a score of 1, components that were not applied were scored 0 (dependent variable, dichotomous). Differences between the frequencies of applying the components by professionals and students (independent variable, dichotom) were analysed using Mann-Withney[15] tests, exact, ($\alpha < 0.05$), two independent sample test) because of the relative small sample size. For the analysis of the effect of experience on the application of the components, the level of experience was determined (interval level) by the number of years of experience. For the professionals, the years of their study and the years of professional experience were added together. The correlation between experience and the application of the components was analysed by means of a Spearman correlation, ($\alpha < 0.05$, double edged)[16].

8.3 RESULTS AND DISCUSSION

8.3.1 FREQUENCY OF APPLICATION OF THE COMPONETNS IN THE DESIGN PROCESS

Except for the category 'user involvement' and some of the components in the category 'state of the art', most of the individual components were applied in at least 60% of the design processes of professionals and students combined (see Table 8.2). The components in the category 'user involvement' were applied in less than half of the processes, except for the component 'observation', that was applied in 68% of the processes The low frequency of applying components of the category 'user involvement' can be explained in several ways. Lack of time is one possible explanation, as 'user involvement' requires both effort and time. Students often complain about the limited time they have for their assignments (which was often mentioned when submitting the assignment). In his research Oijevaar (2009) also found that user involvement is often omitted or reduced in the design process due to a lack of time. The low frequency of applying components in the category 'user involvement' is also consistent with Kujala's (2003) findings. From a review of the literature, she concluded that user involvement has generally positive effects, especially on user satisfaction, but that it is a costly process that requires time and effort.

8.3.2 DIFFERENCES BETWEEN THE STUDENTS AND THE PROFESSIONAL IN APPLYING THE COMPONENTS

The frequencies of the application of the components are shown in Table 8.2. The frequency of applying each components varied the most in the group of students, between 19% and 97%. The frequency of applying the components by professionals varied between 58% and 89% (see Table 8.2). Significant differences between professionals and students regarding the frequency of applying the components were found for eight out of the fifteen components (see Table 8.3). In the category 'user involvement', all components (except the component 'observations') were applied significantly more in the professionals' group. The lowest numbers of significant differences were found in the categories 'state of the art' and 'ergonomic & functional study'. In each category, one component was applied in significantly more processes in the professionals' group (see Table 8.3).

15. In statistics, the Mann–Whitney U test (also called the Mann–Whitney–Wilcoxon (MWW), Wilcoxon rank-sum test, or Wilcoxon–Mann–Whitney test) is an non-parametric test of the null hypothesis that two samples come from the same population against an alternative hypothesis. Unlike the t-test it does not require the assumption of normal distribution, and it is nearly as efficient as the t-test on normal distributions. (Dalen and Leede, 2009)

16. Crosstabs are used to analyse hypotheses about how some variables are contingent upon others. Crosstabs are use if the variables level is nominal or ordinal, (Dalen and Leede, 2009), which is the case in this study. The crosstab analyses were performed double edged.

Table 8.2: Application of the components in the design process

COMPONENTS IN THE DESIGN PROCESS	BACHELOR (16)		MASTER (15)		BACHELOR + MASTER (31)		PROFESSIONAL (19)		TOTAL (50)	
STATE OF THE ART										
state of the art of similar products	15	(94%)	15	(100%)	30	(97%)	15	(79%)	45	(90%)
state of the art of non-relating products	7	(44%)	9	(60%)	16	(52%)	13	(68%)	29	(58%)
technology, science, materials etc. research	5	(31%)	15	(100%)	20	(65%)	14	(74%)	34	(68%)
DESIGN SHAPING METHODS										
designing by sketching or rendering	15	(94%)	15	(100%)	30	(97%)	17	(89%)	47	(94%)
designing maing tangible models (3D)	5	(31%)	12	(80%)	17	(55%)	16	(84%)	33	(66%)
designing by making working models	4	(25%)	11	(73%)	15	(48%)	17	(89%)	32	(64%)
ERGONOMIC & FUNCTIONAL STUDY										
consulting ergonomic guidelines	16	(100%)	9	(60%)	25	(81%)	17	(89%)	42	(84%)
product function risk and mistake analysis	11	(69%)	9	(60%)	20	(65%)	15	(79%)	35	(70%)
function risk and mistake analysis by self-testing	13	(81%)	4	(27%)	17	(55%)	16	(84%)	33	(66%)
function risk and mistake analysis designed product	6	(38%)	8	(53%)	14	(45%)	17	(89%)	31	(62%)
USER INVOLVEMENT (UI)										
questioning users	2	(13%)	4	(27%)	6	(19%)	15	(79%)	21	(42%)
observation	7	(44%)	12	(80%)	19	(61%)	15	(79%)	34	(68%)
feedback on concepts and/or models										
feedback on concepts (2D)	2	(13%)	7	(47%)	9	(29%)	11	(58%)	20	(40%)
feedback on models (3D)	0	(0%)	8	(53%)	8	(26%)	12	(63%)	20	(40%)
feedback on working models	1	(6%)	8	(53%)	9	(29%)	14	(74%)	23	(46%)

Table 8.3: Differences in application: students versus professionals: two sample independent test, Mann-Withney exact ($p < 0.05$)

COMPONENTS IN THE DESIGN PROCESS	U	P
State of the art		
state of the art of similar products	129.500	0.461
state of the art of non-relating products	114.500	0.217
technology, science, materials etc. research	87.500	0.031
Design shaping methods		
designing by sketching or rendering	143.000	0.986
designing by making tangible models (3D)	69.000	0.009
designing by making working models	44.000	0.000
Ergonomic & functional study		
consulting ergonomic guidelines	136.000	0.612
product function risk and mistake analysis	136.500	0.612
function risk and mistake analysis by self-testing	133.000	0.721
function risk and mistake analysis designed product	73.000	0.006
User involvement (UI)		
questioning users	51.000	0.001
observation	98.500	0.076
feedback on concepts and/or models		
feedback on concepts (2D)	65.000	0.010
feedback on models (3D)	40.000	0.000
feedback on working models	32.500	0.000
α= 0.05		

There are at least two possible reasons that could explain these differences. First, a lack of time may have caused design students to apply some components less than professionals. For example, upon handing in their assignments, many students mentioned that they omitted asking 'users for feedback on (working) models' and testing 'the function risk and mistake analysis of the designed product' because of a lack of time; they often their designed products only a day or even a couple of hours before the deadline, which makes it rather difficult to test the designed product. Similar findings were reported by other researchers as well (e.g. Oijevaar, 2009; Kujala's, 2003). A second explanation for the differences found between professionals and students may be that the components 'functional, risk and mistake analysis of the designed product' and having 'feedback of users on the working model' is considered less important by students than by professionals. A student who decides to not apply these components may probably receive a lower grade (which does not necessarily mean failure of the assignment), whereas for professionals the risk of creating a product that will not sell is much higher.

8.3.3 THE EFFECT OF EXPERIENCE ON APPLYING THE COMPONETNS

The experience of the student participants varied between 2 and 6 years; the average years of experience was 2.7 years. The experience of the professionals was between 3 and 20 years (one of the participants had no design (or other) education previous to his job); the average years of experience was 11.7 years. When looking at the correlations between level of experience and the application of the components in the design process, several positive correlations were found. For six out of fifteen components (40%) positive correlations were found between the experience of the (student) designer and the application of the components (Table 8.4). Daalhuizen (2014) also showed that experience influences the way the design process is conducted. The following components showed moderate significant positive correlations with the (student) designer's experience (see Table 8.4): 'designing by making tangible models (3D)' (ρ = 0.319; p= 0.034), 'designing by making working models'(ρ= 0.439; p= 0.003), 'function risk and mistake analysis designed product'(ρ= 0.452; ρ= 0.001) 'questioning users'(ρ= 0.399; p= 0.005) , 'user feedback on models (3D)' (ρ= 0.323; p= 0.031) and 'user feedback on working models'(ρ= 0.469; p= 0.001) (see Table 8.4). Similar results were found in an earlier study about the effect of experience of students on the frequency of applying components in the design process (Kok et al., 2011) for the components 'questioning users' and 'user feedback on models (3D) and/or on working models'.

Table 8.4: Correlations between the years of experience of the designer (student) and the application of the components in the design process

COMPONENTS IN THE DESIGN PROCESS	ρ	p
State of the art		
state of the art of similar products	-0.173	0.186
state of the art of non-relating products	0.258	0.087
technology, science, materials etc. research	0.222	0.142
Design shaping methods		
designing by sketching or rendering	-0.046	0.889
designing by making tangible models (3D)	0.319	0.034*
designing by making working models	0.439	0.003**
Ergonomic & functional study		
consulting ergonomic guidelines	-0.116	0.468
product function risk and mistake analysis	0.134	0.384
function risk and mistake analysis by self-testing	0.134	0.158
function risk and mistake analysis designed product	0.452	0.001**
User involvement (UI)		
questioning users	0.399	0.005**
observation	0.399	0.479
feedback on concepts and/or models		
feedback on concepts (2D)	0.266	0.084
feedback on models (3D)	0.323	0.031*
feedback on working models	0.469	0.001**
α= 0.05		

For six out of the eight components, for which significant differences in that application in the design process of design students and professionals were found, positive correlations were found with the designer's experience. For two of the components ('state of the art of technology, science, materials etc. research' and 'user feedback on 2D concepts') that were applied more by professionals than by students no correlations with experience were found. This suggests that the differences between design processes of design students and professionals is related to the designers' experience for many of the components but other factors (such as the context) can also affect the design. However to ascertain whether these effects are caused by the status of the designer (student or professional) or the experience of the designer, further research is needed with a lager set of data.

8.3.4 STUDY DESIGN

Generalising the results of this study should be done with care. This study was conducted within a specific design domain: seat design. In order to draw more general conclusions, additional research, addressing more design processes and the design processes of different types of products (other than seats), is needed.

8.4 CONCLUSION

The research described in this paper showed differences between design students and professionals for eight out of fifteen components in the design processes. For six of these components, positive correlations between the designers' experience and the frequency of applying these components were found. This suggests that the differences in the design processes of design students and professionals is partly related to the designer's experience and partly to other factors such as the different context in which the designer(-student) works. To generalise these findings, a study with a larger set of data and with different types of design processes is needed.

References

BEIRNE, P., (2011), From Object to Objective: Reframing the Goals of Product Design Education in a Postindustrial Context. *Design Principles and Practices*, Vol.5, 6, ISSN 1833-1874.

BENDER, B., AND BLESSING, L. (2004), On the superiority of opportunistic design strategies during early embodiment design. *8th International Design Conference*, Dubrovnik, Croatia, 117-122.

DAALHUIZEN, J.J., (2014), *Method Usage in Design: How methods function as mental tools for designers*, PhD thesis, chapter 3, 63-96, TU Delft, NL

DALEN ,J., VAN, AND LEEDE, E., VAN, (2009), *Statistisch onderzoek met SPSS for Windows (statistic research with SPSS for Windows)*, uitgeverij Lemma, NL.

GONÇALVES, M., CARDOSO, C., AND BADKE-SCHAUB,P., (2014), What inspires designers? Preferences on inspirational approaches during idea generation. *Design Studies,* vol. 35, 29-53 http://dx.doi.org/10.1016/j.destud.2013.09.001

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2011), *"Methods of the design process: an inventory. ODAM 10nt symposium,Grahamstown, SA 4-6 april*

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2012), The amount of ergonomics and user involvement in 151 design processes. *Work*; vol. 41, Suppl 1:989-96. doi: 10.3233/WOR-2012-0275-989

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2013), The effect of the designers approach on the user experience: an exploratory case study, *More for less: design in an age of austerity*. Cumulus conference Dublin.

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2015A), Components in the design process affecting the perceived product quality. *Ergonomics in Design*, Submitted July 2015.

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2015B), Essentials in the design process for creating comfort in seating products for vehicles. *Applied Ergonomics*. Submitted June 2015.

KUJALA, S., (2003) User involvement: A review of the benefits and challenges, *Behaviour & Information Technology, vol.* 22, 1,pp. 1-16.

LEMONS, G., CARBERRY, A., SWAN, C. , AND ROGERS, C., (2010), The benefits of model building in teaching engineering design. *Design Studies, vol. 31*, 288-309, doi:10.1016/j.

MAD-FACULTY, (2010), *"Zelfevaluatierapport Productdesign" (Self-evaluation report Product Design)*, Genk, BE

MOTTE, D., AND BJÄRNEMO, R. (2004), The cognitive aspects of the engineering design activity – a literature survey. *TMCE 2004 , April 12-16, 2004*, Lausanne, Switzerland.

OIJEVAAR, K.J., DEN, AND JOVANOVIC, M., (2009), *User Involvement in the Design Process of Multifunctional Buildings*. In Wamelink, H., Prins, M. & Geraerdts, R. (Eds.),(2009), CR09, Changing Roles: New Roles and New Challenges, (pp. 485-495). Delft: University Press, NL.

PAHL, G., BADKE-SCHAUB, P., AND FRANKENBERGER, E. (1999), Résumé of 12 years interdisciplinary empirical studies of engineering design in Germany. Design Studies, Vol. 20, 5, p 465–480.

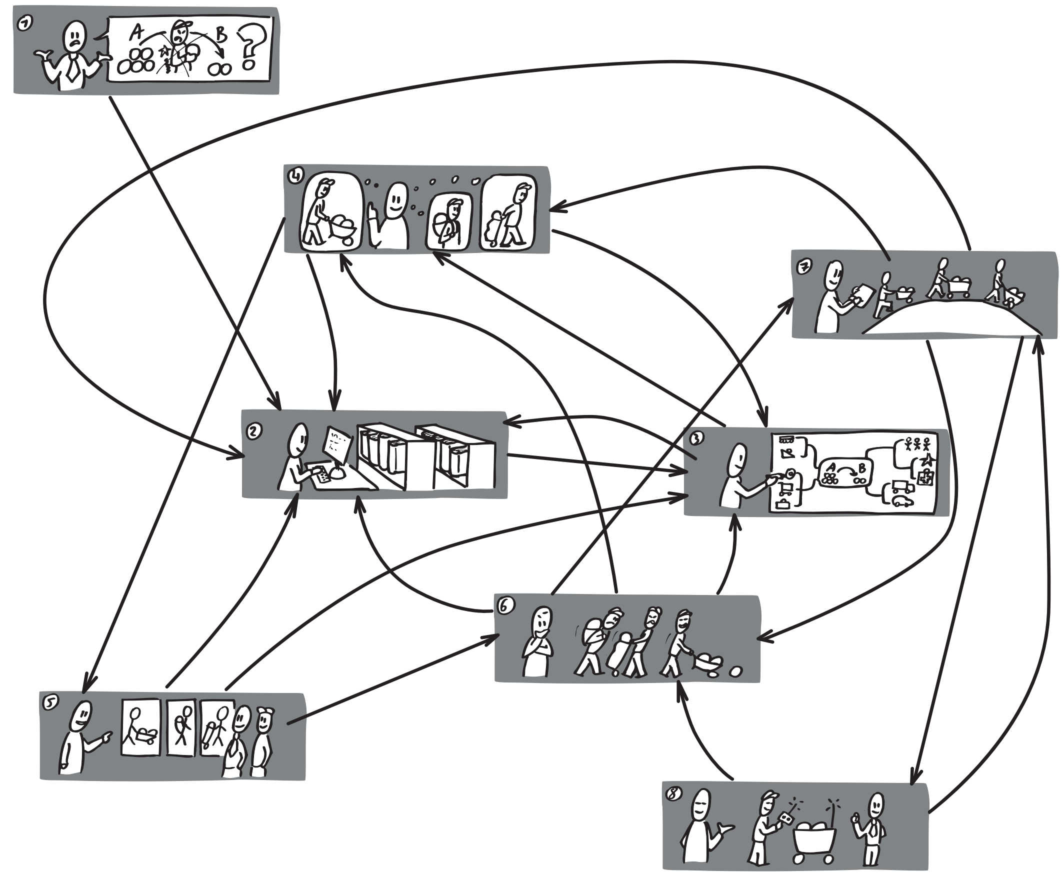
SCHIFFERSTEIN, H.N.J. AND HEKKERT, P. (EDS.), (2008), *Product experience*. Elsevier Science.

VINK, P., BAZLEY, C., KAMP, I., AND BLOK, M., (2012), Possibilities to improve the aircraft interior comfort experience. *Applied Ergonomics*. Vol. 43, 354-359. Doi: 10.1016/j.apergo.2011.06.011

VINK, P., AND HALLBECK, S., (2012), Editorioal: Comfort and discomfort studies demonstrate the need for a new model., *Applied ergonomic. Vol. 43*, 271-276. Doi: 10.1016/j.apergo.2011.06.001.

Discussion Part III

Because most of the studies described in Part I and II were based on design processes of students it is difficult to generalize the conclusions to the design processes of professional designers. Therefore, in this last part of this PhD thesis, a comparison was made between design education and 'the real world'. In this part the sub-questions "Are there differences in the design process of design students and professional designers?" and "Are design teachers able to estimate the end users' product experience?" were addressed in Chapter 7 and 8. The results in the studies addressed in Chapter 7 and 8 showed differences as well as similarities between education and the real world. First of all the design teachers are only partly able to estimate the user's perception of products. Secondly, the design processes of student designers are only partly similar to the design processes of professionals.
When looking at the assessment of products by design teachers and potential users (Chapter 7), it was found that users gave higher scores than design teachers did (see Figure 7.2.). Several reasons could explain why users tend to give higher scores than the teachers do. As mentioned by designers in 7.2, users might prefer products that are functional, user friendly, beautiful and familiar to them. New products need to be related to products they already know. Although these issues are important for designers too, they also take the innovation of a design into account, which users might not do (see 7.3.2). Another explanation for the higher scores given by the users could be that the users might be happy that someone is finally addressing their problems by trying to make a better design, and therefore give high scores in the assessment. Furthermore, users might feel empathy for the student, giving more generous scores out of sympathy. The causes of the differences in scoring between the teachers and potential users were not further studied in this research. To be able to elucidate the reasons why users tend to give higher scores, further research is needed, for example by using a large variety of jury members and gather more in depth data by interviewing jury members after scoring.



Epilogue

9. Epilogue

9.1 GENERAL CONCLUSIONS

The main goal of the research described in this PhD thesis was to study which design process components can contribute to a better perceived product quality. In this research first the components applied in the actual design processes were studied. The second part of this PhD thesis investigated how these individual design process components related to the perceived product quality. The last part of this PhD thesis studied the ability of design education teachers to assess users' perceived product quality. Also, the design processes of students were compared to the design processes of professional designers in order to explore whether parts of the research based on student data in this thesis can be generalized. This epilogue consists of an overview of the main findings, a discussion on the generalisability and the quality of the data gathered. It also provides a reflection on the studies conducted, and proposes recommendations for further research.
The main research question of this PhD thesis is:

Which design process components contribute to a better perceived product quality?

Four sub-questions were asked to achieve this goal:

1) Which components can be distinguished in the design process?
2) How do individual design process components relate to the perceived product quality?
3) Are there differences in the design process of design students and professional designers?
4) Are design teachers able to estimate the end users' product experience?

The Product Design – Quality – Model (PDQ Model, chapter 1 & see figure 9.1) explains the relationship between the design process components and the perceived product quality.

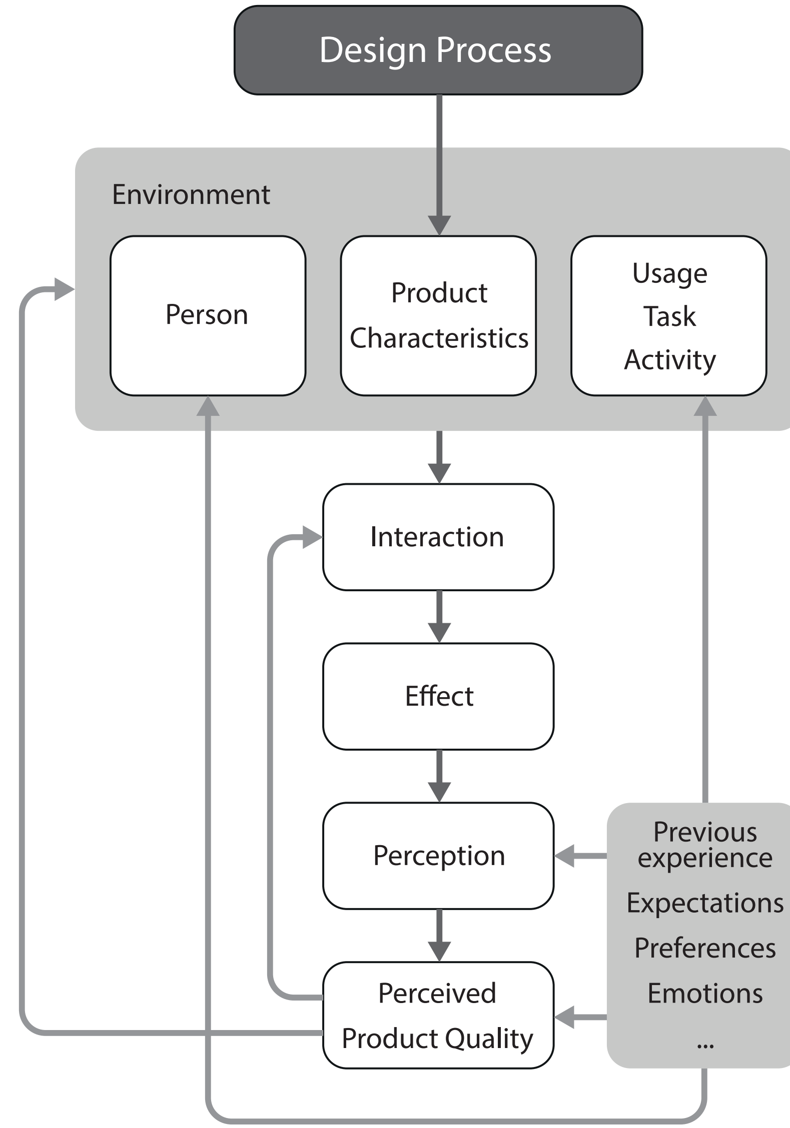


Figure 9.1: The Product Design - Quality Model, inspired by the comfort model of Vink and Hallbeck (2012), and discussed in Chapter 1, Figure 1.3.

Summarization of the main findings of this thesis are found in Table 9.1, Table 9.2 and Table 9.3.

Table 9.1: Key findings thesis Part I

FINDINGS	CHAPTER
In our study the most frequently applied components in the design processes of design students were, the design process component 'state of the art of similar products' and the components in the category 'ergonomic and functional studies' and 'design shaping techniques' 'User involvement' was the least applied component.	2
Design students who had experience in ergonomics (e.g. more courses in ergonomics) were more likely to apply the design process components 'functional, risk and mistake analysis by self-testing' and 'functional and risk and mistake analysis of the designed product', and were less likely to consult 'ergonomic guidelines'.	3
Design students were more likely to do functional, risk and mistake analysis and to gather user feedback on concepts and models in their design processes when a specialist in ergonomics was involved in student supervision.	3
However when a user involvement specialist in was included in student supervision, design students are more likely to question (interview) users in their design processes.	3

Table 9.2: Key findings thesis Part II

FINDINGS	CHAPTER
The application of the design process components 'design shaping by making (working) models', 'functional, risk and mistake analysis' (with or without self-testing), 'functional, risk and mistake analysis of the designed product' and 'user feedback on (working) models' had a moderate positive effect on the perceived product quality of products (designed by students) for people with specific needs or a disability.	4
When re-designing a product, the application of the design process component 'function, risk and mistake analysis of the designed product' had a moderate positive effect on perceived product quality of products (designed by students).	5
The design process components 'involving users by asking feedback on 2D concepts' and 'applying design research tools in the design process' had a moderate positive effect on the perceived product quality of newly designed products (designed by students).	5
'Consulting ergonomic guidelines' in the design process had a moderate negative effect on the perceived product quality of newly designed products (designed by students).	5
Professionals (involved in design processes) considered the following design process components important for comfort aspects when designing vehicle seats: 'prototyping', 'function, risk and mistake analysis' (with or without self-testing), 'function, risk and mistake analysis of the designed product', 'designing by making working models', and 'focus groups and questioning users'.	6

Table 9.3: Key findings thesis Part III

FINDINGS	CHAPTER
Design teachers were more capable of assessing how users perceived product quality for users with no disabilities or specific needs than for users with disabilities or specific needs.	7
There are many differences in the situations of student designers and professionals in (experience, contexts disposable budget, machinery and infrastructure). However, there were no differences between the design processes of design students and professional designers in terms of the frequency of application in the following design process components: the components in the category 'state of the art' (except for the component 'state of the art of technology, science, materials etc. research'), the components in the category 'ergonomic & functional study' (except for the component 'function risk and mistake analysis of the designed product') and the individual components 'design shaping by sketching and rendering', and 'observing users'.	8
Compared to design students, the following design process components were applied more often by professional designers (compared to design students): the components in the category 'user involvement' (except the component 'observation'), and the components 'function risk and mistake analysis of the designed product', 'making (working) models' and 'state of the art of technology, science, materials etc., research'.	8
There is a relationship between the designer's experience and the applied design process components: the following design process components were applied more often amongst more experienced designers than less experienced designers: 'making (working) models', 'function risk and mistake analysis of the designed product', and all components in the category 'user involvement' (except the components 'observation' and 'feedback on 2D concepts').	8

9.2 GENERALISATION AND REFLECTION

The results of the research described in this thesis indicate that several components of the design process affect perceived product quality. However, since the research described in this PhD thesis is largely based on data from students' design processes, a generalisation of the findings to designers should be conducted with great care. Reflections on this point are discussed and described in the next paragraphs.

9.2.1 PARTICIPANTS

An important aspect in generalising the results of the research described in this PhD thesis is the fact that most of the design processes included in the studies were executed by design students and not by professional designers. Moreover, the students whose design processes were assessed were recruited at a single education institute in Belgium. During the course of this research, several attempts were made to obtain data from professional designers, albeit with very little success. Gathering data from professional designers by means of surveys, on paper, online and distributed in various ways:

- by asking design schools and universities to distribute the survey to their alumni;
- by introducing the research in a conference presentation and asking professional designers personally to fill in the survey;
- by asking professional designers to distribute the survey in their professional networks;
- by directly contacting professional designers.

Most of the design schools, universities and interest groups contacted did not respond to the requests to distribute the survey and those who did respond did not want to distribute a survey. The main reason for not participating, for schools, universities and interest groups, was a lack of time. The requests made for survey distribution at conferences and surveys sent to designers directly resulted in few responses.

In addition to searching for possibilities to gather data on professional designers' design processes, an in-depth study conducted with professionals at a conference on seat design was carried out.

Professional designers participated in a full-day workshop, which resulted in the valuable data described in chapter seven. These data allowed exploration of similarities and differences between design processes of design students and professionals, and as such provided an indication of the generalization of the findings reported in this PhD thesis. This study also showed that the level of experience of designers can have an effect on the design process components they choose to use. However, it was difficult to distinguish whether the effect was related to the experience of the designer or the context (time money, available machinery and infrastructure, etc.) the (student) designer was working in.

9.2.2 DESIGNER STUDENTS VERSUS PROFESSIONAL AND EXPERIENCED DESIGNERS

Similarities and differences between the approach of the design processes of student designers and of professionals/more experienced designers were analysed in the study described in chapter eight. For almost half design process components studied, no differences in frequency of applying was found between the students and professionals/more experienced designers. The components in the design processes for which significant differences in frequency of applying were found were always applied more frequently by the professionals/more experienced designers. There are several possible explanations for these differences:

(1) Design strategy is a behaviour. Behaviour is partly educated (Smit, Pillen and Tjepkema, 2010;Veen and Wal, 2012). A part of this education takes place in the design education. The professional participants did not study at the LUCA School of Arts. The professionals might have learned to design in a different way than the design students and therefor apply different design process components.

(2) During their career, designers experience the effects of certain design process components on the product quality, which can result in using certain components more often (as mentioned in the focus-group discussion, chapter Six). Designers tend to apply design process components they are familiar with more than other design process components (Baber and Mirza, 1988; Stanton and Young, 1998).

(3) A young designer is still learning to apply the components which can result in needing more time to apply the design process components, for example the preparation, execution and data processing of a user involvement e.g., testing some features takes more time as the young designer is not experienced with user involvement. Therefore, less experienced designers need more time to apply other design process components than the more experienced designers do, and have less time to apply other design process components. Design process components are sometimes not applied due to a lack of time (Chapter 8; Oijevaar, 2009; Kujala, 2003)

(4) Experience influences the way a design process is tackled. Curry (2014) stated that there is a significant difference between the way novice designers approach a design problem compared with how expert designers approach a design problem. The novice designers usually apply a "depth-first" approach to problem solving, whereas the expert strategy is usually more top-down and breadth-first approach'. Novice designers tend to focus on understanding the problem through analysis and research, while expert designers tend to prioritize criteria to focus on an approach to the problem (Curry, 2014). This could explain why the student designer applied certain design process components less often than professionals do.

(5) The context (time money, available machinery and infrastructure, etc.) of student designers and professional designers is different (see Chapter Eight) and has an effect on the choice of which design process components will be applied in the design process.

As shown in Chapter 4 and 5, the design process components can affect the perceived product quality. Therefore it can be concluded that design education can have some effect on the perceived product quality of future designers' products. This can be achieved by implementing the design process components, which can have a positive effect on the perceived product quality, (more) in the curriculum and by emphasizing the importance of these design process components. However, as mentioned earlier the design strategy of professionals is only partly moulded during her/his education and therefore the effect of design education on the perceived product quality is limited.

9.2.3 REFLECTION ON THE DATA COLLECTION

The first data sets used in this research (Chapter 2 and Chapter 3) were based on written reports about students' design processes. Although such reports may provide more information than a structured way of collecting information about the design processes, (e.g. by means of questionnaires), they are more difficult to standardise and analyse. Therefore, from mid-2010 (Chapters 4 to Chapter 8), data were collected by administering questionnaires to students after finishing their design assignments. Although this allowed for a more structured data collection, the information about the design processes gathered by means of these questionnaire may contain biases, as shown in other studies (e.g. Bakker et al., 2014; Choi and Comstock, 1975). The questionnaires consisted of a list of Design Process Components. The participants were instructed to mark the components that they applied in their design process. Although there was an option to add components that were not mentioned in the list, students rarely added new components. Therefore, it is possible that certain design process components were not reported although they were applied in reality. Socially desirable answers could not be excluded in the questionnaires (for example indicating that certain components were applied when they were in reality not applied). The mere fact that certain components were mentioned in the questionnaire may have been interpreted by students that they were supposed to apply these components. In the studies of Chapter 2 and Chapter 3 it was noticed that students did not mention all the design process components in the design reports. In order to avoid missing data (design process components which were applied but not mentioned in the reports) and in order to have more standardised data a survey was created based on the data of the studies in Chapter 2 and 3. Additionally, to limit the risk of biases caused by socially desirable answers, all the questionnaires were completed after participants had received their grades and feedback. So, students could be certain that the questionnaire did not influence their grades.

This PhD research did not take into account the effect of factors such as the designers empathy towards the user or the designers aptitude, which can also have an effect on the design process and the user experience of the designed product. Concerning empathy Rijn et al. (2011), concluded in their study that designers who had direct contact with the users had more empathy and were more motivated to design products for these users than designers who had no contact with users during the design process, which influenced the quality of the product concepts. Donagh and Thomas (2010), stated in their research about empathy supporting innovation that empathy is the way to bridge the gap that exists between lived experiences, user needs, and existing products that fail to satisfy the user. Regarding the designer's aptitude Groenendijk et al. (2013) concluded that observation had beneficial effects on creativity for high aptitude students, but not for low aptitude students. The effect of factors such as empathy or aptitude on the design process and perceived product quality was not studied in this PhD research. A designer with high empathy towards the users might design products with good perceived quality even without applying the components which can have a positive effect on the perceived product quality. Similar a designer with a low empathy towards the users might create products with bad perceived product quality even if she/he applied the components which can result in better perceived product quality. The designers aptitude might have a same effect on the perceived product quality. The effect of empathy and designers aptitude on the perceived product quality is an interesting subject for future research.

Other factors not specifically studied in this research are design students' skills and talents. A talented designer might create products with good perceived quality without applying the design process components that can affect the perceived product quality positively and vice versa. Also not further focused on in this PhD research is the quality of applying the design process components. For example, if the components which have a positive effect on the perceived product quality are applied poorly most likely will not result in good perceived product quality. Since designer students are still learning how to design and how to apply the design process components, it can be assumed that design student probably apply the design process components less accurate than professionals. It is therefore possible that the correlations found between the design process components on the perceived product quality is actually higher when the designer is more experienced. Interpretation of the effects of these factors on the perceived product quality warrants further research.

In this PhD thesis, perceived product quality focuses specifically on the functionality and usability, design (aesthetics, shape, colour, texture, etc.) and maintenance. Bhuian (1997) distinguishes extrinsic and intrinsic contributions to the perceived product quality. The qualities studied in this research are intrinsic qualities of the product, to change these qualities the product itself has to be changed. Extrinsic qualities, such as watching others using it or the products brand name and reputation were not included in this research. The emotional experience or product emotion (Desmet, 2003) is also not included in the perceived product quality as defined in this research. Although the assessors of the perceived product quality were specifically asked to assess only the functionality and usability, design and maintenance the score given for the products could subconsciously be influenced by the extrinsic or emotional qualities. If a user had bad experiences with round pencils (because they easily role of the table), a round marker might evoke negative feelings and the user might give a lower score for perceived product quality (even if it doesn't role because it has a clip on the shell).

9.2.4 DESIGN EDUCATION VERSUS REAL WORLD

Most of the studies in this research were done in an educational context, which implicates that generalising conclusions should be done with care. When looking at the capability of (designers and) design teachers to estimate the users' perception, it was found that design teachers are not always good estimators of the users perception (Chapter 7). As mentioned in 7.4.1 a possible explanation for this is that it is simply impossible for a teacher to have in-depth knowledge of the needs of the large variety of specific users their students design for. The lack of correlation between the product assessments of the teachers and of the users emphasizes the importance of involving users in the assessment of products in design education. It is important for designers and design education to be aware of their limited capability to estimate the users' experience and importance of user involvement and assessment in the design process. Ample research has shown the importance of user involvement in design (Wever, Kuijk and Boks, 2008; Sleeswijk Visser, 2009; Nielsen, 2010; Sanders, 2006), it is therefore important or design education to involve users in the design process as well as in the assessment of the designed products.

9.2.5 GENERALISE WITH CARE

The studies in this research were mainly executed with designer students of on particular design school, LUCA School of Arts, Genk, Belgium. The generalisation of these results needs to be done with care. An important issue when generalizing these results is that the design school at which the design students participating in our research studied, has a focus on arts and socially relevant questions rather than the demand of the design industry. The academy used in these studies trains students in skills and knowledge that allows them to create products that answer socially relevant problems. In this academy, the design students are trained to create (design) answers to problems based on contextual research and focus on the social situation in which the problem occurs. Consequently, the student designers pay less attention to the production feasibility (for example large-scale production or availability if technology and materials, etc.) production costs or marketing than student designers of other institutions or professionals might do. The design processes of these design students are therefore not representative for professional designers, as discussed in 9.2.2), for half of the studied design process components significant differences in frequency of applying were found (Chapter 8).

As discussed in 9.2.4, the perceived product quality was focused specifically on the functionality and usability, design (aesthetics, shape, colour, texture, etc.) and maintenance in this research. Other factors such as for example emotional experience and extrinsic product characteristics were not included were in this study. Therefore these studies don't reveal any information about the effect of the design process components on these factors although they are a part of the product experience.

As mentioned in the introduction, the design processes were approached in a procedural way, process to study the relation between the components and the outcome of the process. The procedural approach focussing on the whole process of concrete design project, (Wynn and Clarkson, 2005). This approach was warranted by the type of data studied in this research, as the focus was on the relationship between components in the design process and perceived product quality. The other approaches described in the classification of Wynn and Clarkson (2005): the abstract approach and the analytic approach, would not have been useful in this research. An abstract approach might not have revealed possible correlations, because the design process would not have been studied in terms of concrete design process components. Research on the abstract approach may have revealed the effect of more abstract factors, such as the designer's philosophy or empathy with users. Based on the data in this study, it was not possible to conduct a more analytic research approach, for example to study whether the effect of certain components on the perceived product quality was different if these would be applied in a different phase of the design process because the application of the components in the different phases of the design process were not studied.

None of the correlations found between the design process components

were strong. The moderate character of these findings may be the result of interactions between individual components, not analysed due to the setup of the studies, as was mentioned in Chapter five. As such, some of the design process components that have no individual effect on perceived product quality, may have had a joint effect when applied in combination with other components. The data sets used in this research were too small to analyse such interference effects. Other factors such as the cultural background of the designer, aptitude and the designer's empathy towards the user, the designers skills and talents, (see 9.2.3), and the context (time money, available machinery and infrastructure, etc.) in which the designer is working, (see 9.2.2) may affect the perceived product quality as well and were not included in this study.

9.2.6 FUTURE RESEARCH AND RECOMMENDATIONS

Several major topics were identified for future research based on the research described in this PhD thesis:

(1) In this research the effect of the design process components on the perceived product quality was based on data of design students, not professionals. It is therefore warrant to study the effect of the design processes of professionals on the perceived product quality in order to generalize the results of this research. However it is difficult to obtain information concerning the design processes of professional designers, as they sometimes do not want to share their unique approaches and many have limited time for additional research.

(2) The products designed by the student participants were concepts and models, not advanced working prototypes. Therefore, the product testing and assessments were limited. It would be of interest to analyse the correlation between the design process components and the perceived product quality of products with good working prototypes (or of products which are already on the market), to see whether the same components affect the perceived product quality assessed by people using the product in daily life. Features, possibilities and limits of products might appear to be different when a prototype of the product is tested briefly like in our study, then when it is frequently used. However, there are challenges in performing this research as it is difficult to obtain data from professional designers who create products that are on the market and the design processes of students usually do not result in advanced prototypes.

(3) As mentioned in Chapter Five and 9.2.5 there might be interactions between the different design process components, some of the design process components that have no individual effect on perceived product quality, may have had a joint effect when applied in combi nation with other components. Future research should include a larger

set of data in studying the design processes to analyse possible interactions between the individual components of the design processes and possible other relevant factors that were not included in this study) on perceived product quality. It would be interesting to add other educations and products that are not tangible or functional.

(4) Different schools have different approaches towards design. It would therefore be interesting to compare the design processes of design students from different design schools, academies and universities to understand whether the different approaches and visions of the schools result in different design approaches acquired by the students.

(5) Another interesting topic for further research could be to study the effect of other factors such as the designer's aptitude skills, talents and empathy, (see 9.2.3), and the context (time money, available machinery and infrastructure, etc.) in which the designer is working, (see 9.2.2 on the perceived product quality). Most of the studies in this research were done in an educational context, which implicates that generalising conclusions should be done with care.

(6) The effect of intensity and the quality with which the design process components are applied on perceived product quality is another interesting topic for future research.

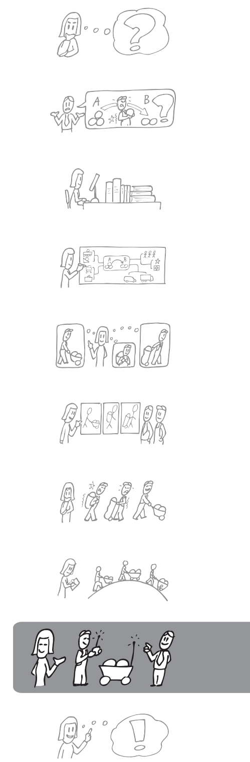
Depending on the type of design (redesigned or newly designed) or the type of users different design process components can have a positive effect on the perceived product experience (see 9.1 and Chapter 4 and 5). By implementing and emphasising (more) on these components design education can affect the user experience.

The following recommendations can be formulated towards design education:

(1) It is recommended to train the design process components, which can have an effect on the perceived product quality, during the education of the design students and to teach students which design process components are important in the different type of designs :

- When designing for people with specific needs or a disability following design process components should be emphasised:
  - o design shaping by making (working) models
  - o design shaping by making (working) models of existing products (analysis phase) and of the designed product (evaluation phase)
  - o user feedback on (working) models.
- When redesigning a product, the application of the design process component: function, risk and mistake analysis of the designed product should be emphasised.
- In the design process of newly design products special attention should be given to: involving users by asking feedback on 2D concepts and applying design research tools in the design. It should also be emphasised that strictly following guidelines can have an negative effect on the perceived product quality.

(2) Because of the limited ability of design teachers to estimate the users' perception of products designed for users with disabilities or special needs, these users should be involved in the assessment as well as the design process of student projects and products.



References

BEIRNE, P., (2011), From Object to Objective: Reframing the Goals of Product Design Education in a Postindustrial Context. *Design Principles and Practices*, Vol.5, 6, ISSN 1833-1874.

BABER, C. AND MIRZA, M.G., (1988), Ergonomics and the evaluation of consumer products: surveys of evaluation practices, in *Human Factors in Consumer Product Design*, Stanton, N.A., Ed., Taylor & Francis, London.

BAKKER I, VOORDT, T., VAN DER, VINK, P., AND BOON, J., DE, (2014), The use of questionnaires in colour research in real-life settings: in search of validity and methodological pitfalls. *Theoretical Issues in Ergonomics Science*. vol. 15, 5, pp. 464–478 , doi: 10.1080/1463922X.2013.815287

BHUIAN, S. N. (1997), Marketing cues and perceived quality: Perceptions of Saudi consumers toward products of the U.S., Japan, Germany, Italy, U.K., and France. *Journal of Quality Management*, vol. 2, 2, pp. 217-235.

BONO, E., DE, (1990), *Lateral Thinking: Creativity step by step*. Harper& Row, New York, USA.

CHOI, I.C., AND COMSTOCK, G.W. (1975). "Interviewer Effect on Responses to a Questionnaire Related to Mood." *American Journal of Epidemiology*. Vol. 101, 1, pp. 84–92.

CURRY, T. (2014). A theoretical basis for recommending the use of design methodologies as teaching strategies in the design studio. *Design Studies*, vol. 35, pp. 632-646.

DESIGN ACADEMY EINDHOVEN (2015), *Curriculum product design* retrieved May 2015 from: http://www.designacademy.nl/

DESMET, P.M.A. (2003). A multilayered model of product emotions. *The Design Journal*.

DIJKSTERHUIS, A.P.,(2007), *Het slimme onbewuste: Denken met gevoel* (the Smart Sub-consciousness: thinking with senses). Promentheus Bert Bakker.

DONAGH D., MC, THOMAS J., (2010), Rethinking Design Thinking: Empathy Supporting Innovation. *Academy of Management Journal*, Vol. 3, 8, pp. 458-464. Doi 10.4066/AMJ.2010.391

GROENENDIJK, T., JANSSEN, T., RIJSLAARSDAM, G., AND BERGH, H., VAN DEN, (2013), Learning to be creative: The effects of observational learning on students' design products and processes. *Learning and instruction*, Vol. 28, p35-47.

NORMAN, D. (2015), *The Research-Practice Gap, Essays, retrieved dec 5, 2010*, from. Don Norman: Design for People: http://www.jnd.org/dn.mss/the_research-practice_gap_1.html

NIELSEN, J., (2010), Usability 101: introduction in usability. *Alertbox*, retrieved may 2010,from www. useit.com.

KORTHAGEN, F., (2004) Zin en onzin van competentiegericht opleiden. (Sence and non-sence in competences driven training) *VELON Tijdschrift voor Lerarenopleiding (journal for Teacher-Training, 25 (1).*

KUJALA, S., (2003), User involvement: A review of the benefits and challenges, *Behaviour & Information Technology, Vol.* 22, 1, pp. 1-16.

LUCA SCHOOL OF ARTS (2015), *Curriculum productdesign* retrieved May 2015 from: http://www.luca-arts.be/brochure-productdesign.

OIJEVAAR, K.J., JOVANOVIC, M. , AND OTTER, A.F.H.J., VAN DER, USER INVOLVEMENT IN THE DESIGN PROCESS OF MULTIFUNCTIONAL BUILDINGS. IN WAMELINK, H., PRINS, M. & GERAERDTS, R. (EDS.),(2009), CR09, *Changing Roles: New Roles and New Challenges*, Delft: University Press, NL, pp. 485-495.

PAHL, G., BADKE-SCHAUB, P., AND FRANKENBERGER, E. (1999), Résumé of 12 years interdisciplinary empirical studies of engineering design in Germany. *Design Studies*, Vol. 20, 5, p 465–480.

RIJN, VAN, H., SLEESWIJK VISSER, F., STAPPERS, P.J., AND O¨ ZAKAR, A.D., (2011), Achieving empathy with users: the effects of different sources of information. *IJ CoDesign*, Vol. 7, 2, pp. 65–77.

SANDERS, L., (2006), Design Serving People. *Cumulus Working Papers*; Publication Series G, University of Art and Design Helsinki.

SLEESWIJK- VISSER, F., (2009), *Bringing the everyday life of people into design*. PhD Thesis, TU Delft, The Netherlands, NL.

STANTON, N.A. AND YOUNG, M. (1998), Is utility in the mind of the beholder? A review of ergonomics methods, *Appl. Ergonomics*, vol. 29, 41–54.

SMIT, C., PILLEN, P. AND TJEPKEMA, S. (2010) Veranderen van gedrag (Behaviour Change) in: *Wetenschap en toepassing van breinkennis (Science and Application of Brain Knowledge)*, Bohn Stafleu van Loghum, pp 85-93, doi: 10.1007/978-90-313-7816-6_6, BE

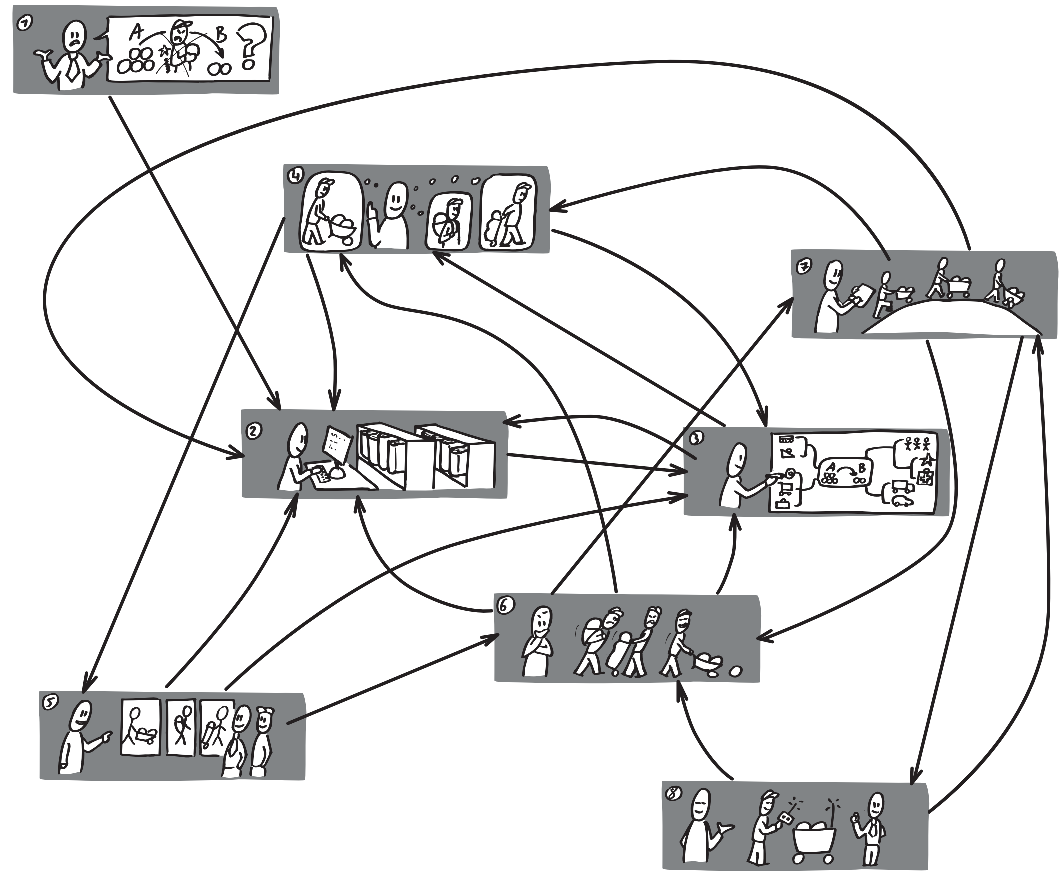
TIEMEIJER, W.L., THOMAS, C.A., AND PRAST, H.M. (RED), (2009), *De menselijke beslisser* (the human decision maker). WWR, Amsterdam University Press, e-ISBN 978 90 4851 199 0

TU DELFT, (2015), *Curriculum industrial design* retrieved May 2015 from: http://www.tudelft.nl/studeren/bacheloropleidingen/overzicht-opleidingen/industrieel-ontwerpen/

U GHENT (2015) *Curriculum industrial design* retrieved May 2015 from: https://prd.oasis.ugent.be/studiekiezer-web/nl/afstudeerrichting/EM7BOU

VEEN, T., VAN DER, (2012), Leren: een complex en onzichtbaar proces. (learning a complex and invisible process) *Van leertheorie naar onderwijspraktijk*. (*From education theory to education practice)* Noordhoff Uitgevers Groningen|Houten, pp. 14-22.

WEVER, R., KUIJK, VAN, J., AND BOKS C, (2008), User-centred Design for sustainable Behaviour. *International Journal of Sustainable Engineering* Vol. 1, 1.



Summary

Summary

Historically one of the main aims of design is to analyse the cultural and social context in order to create progress in the form of everyday experience (Beirne, 2011). Product designers can contribute to good experiences by creating products with good perceived product quality. In order to create a product that has a good perceived quality, designers need to anticipate users' needs, wishes, and expectations, which are each uniquely influenced by the constantly changing society and technological progress. A product that has a good perceived quality can, amongst others, be achieved by conducting usability studies (e.g. Dumas, 2007), by applying principles from human factors and ergonomics (e.g. Dul et al., 2012; Lee, 2006), by following a participatory design approach (e.g. Luck, 2003) or a human-centred design approach (Vink et al. 2008) in the design process. Given this large array of resources for designers, one might expect a large number of good quality products that meet the users' needs. However, such needs, wishes and expectations are still often not fulfilled (Norman, 2010, Den Ouden, 2006; Nielsen, J. 2012; Van Kuijk, 2009). The goal of this PhD research was to to study which design process components can contribute to a better perceived product quality. In order to be able to answer this question a better understanding of the relationship between, on the one hand, the steps, tools and methods used in the design process and, on the other hand users' product quality experience is needed. These steps, tools methods and actions are referred to as 'design process components' and are the central elements in this PhD thesis.

The research described in this thesis focuses especially on functional tangible products and was mainly based on the design processes of design students in one specific school. The latter means that generalization of the results should be done with care.

The main research question was: 'Which design process components contribute to a better perceived product quality?' following sub questions were formulated:

1) Which components can be distinguished in the design process?
2) How do design process components correlate to the perceived product quality?
3) Are there differences in the design process of design students and professional designers?
4) Are design teachers able to estimate the end users' product experience?

(1) In order to answer these questions the components that can be distinguished in the design process were studied as well as the frequency in which these components are actually applied in practice. The results showed that components in the category 'ergonomic and functional studies' are applied most often, and components in the category 'user involvement in the design process' are applied the least often in the design processes of designer students.

(2) Besides identifying the design process components, the effects these components have on the perceived product quality were studied (second sub question). This was done both on a general level and in a specific case study focussing on designing for people with special needs (such as hospitalized children). These studies showed that when re-designing a product, the application of 'function risk and mistake analysis of the designed product' have a positive effect on perceived product quality of re-designed products (designed by students). Using 'ergonomic guidelines' in the design process was found to have a negative effect on perceived product quality of newly designed products. 'Involving users' by asking feedback on 2D concepts' and 'applying design research tools' in the design process had a positive effect on perceived product quality of newly designed products (designed by students). The application of 'design shaping by making (working) models', 'function, risk and mistake analysis' and 'user feedback on (working) concepts and models' had a positive effect on the perceived product quality of products for people with specific needs or a disability.

(3) The third research sub question addressed the ability of design teachers to estimate the end users' perceived product quality. The study showed that design teachers were able to estimate how users perceived the quality of products for people with no disabilities and no specific needs. Estimating the perceived product quality for people living with disabilities or specific needs turned out to be more difficult for design teachers.

(4) A comparison of the design processes of students with the design processes of professionals showed that professional designers question users more often and also collect user feedback on working models more often in their design process. More experienced designers tend to apply ergonomic and functional studies and involve users more often in their design process than their less experiences colleagues do.

Based on this research it is concluded that: the perceived product quality can be influenced by the components in the design process. The effects are limited as only moderate correlations were found. Other factors such as the designers aptitude or the designer's empathy with the user probably

also affects the perceived product quality. By paying enough attention to these components in the design process (in education) positive effect on the perceived product quality could be expected. In order to train design student to be able to create products with good perceived quality design education emphasis on the design process components is needed to influence the perceived product quality positively. This can be achieved by paying attention to the design process components in the curriculum of design students and by involving users in the design processes and assessment of products designed by students. Especially some of the categories ergonomic and functional study, user involvement and design research tools seem to be important.

References

BEIRNE, P., (2011), From Object to Objective: Reframing the Goals of Product Design Education in a Postindustrial Context. *IJ Design Principles and Practices*, Vol.5, Issue 6, ISSN 1833-1874.

DUL, J., BRUDER, R., BUCKL, P., CARAYON, P., FALZON, P., MARRAS, W.S., WILSON, J.R., AND DOELEN, B., VAN DER, (2012), A strategy for human factors/ergonomics: developing the discipline and profession. *Ergonomics*, 1–27.

DUMAS, J. (2007), The great leap forward: The birth of the usability profession (1988-1993), *Journal of usability studies* Vol. 2, Issue 2, USA, February 2007, pp. 54-60.

KUIJK, VAN, J.I., PREIJDE, E.E. , TOET, E.N., AND KANIS, H. (2009), Expected versus experienced usability: what you see is not always what you get. *IEA 2009: the 17th world congress on ergonomics*, August 9-14, Beijing, China, IEA.

LEE, L. (2006), *Learning Spaces: Human-Centered Design: Guidelines*. Educause, 2006.

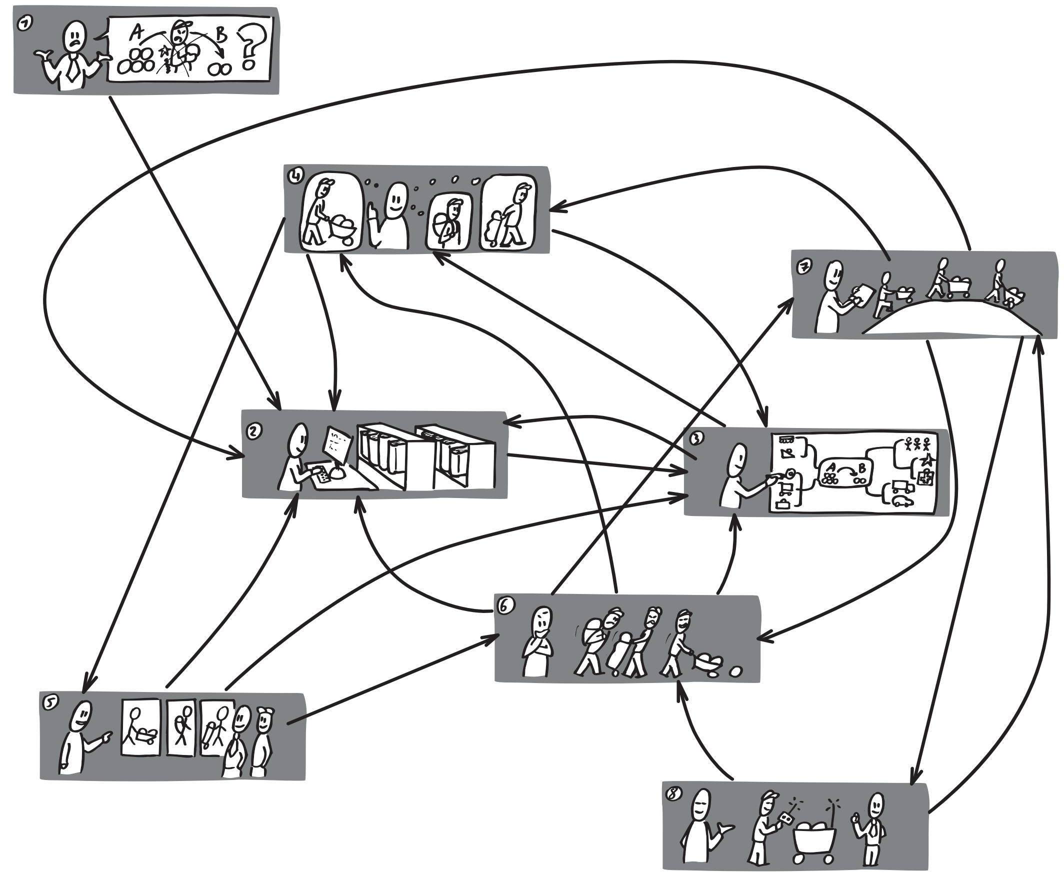
LUCK R., (2003), 'Dialogue in participatory design', *Design Studies*, UK., November, pp 523-535.

NIELSEN, J. (2012), Usability 101: introduction in usability. *Alertbox*, ,from www. useit.com, January 4, 2012.

NORMAN, D. (2010), The Research-Practice Gap, Essays & Technology first, needs last: the research-product gulf. interactions, 17(2), 38-42, http://www.jnd.org/dn.mss/technology_first_needs_last.html, 2010.

OUDEN, E., DEN, (2006), *Development of a design analysis model for consumer complaints: revealing a new class of quality failure*. PhD Thesis, TU Eindhoven, NL.

VINK P., IMADA A.S., AND ZINK K.J., (2008), Defining stakeholder involvement in participatory design processes, *Applied Ergonomics* 39, USA, pp 519–526.



Samenvatting

Samenvatting

Het doel van design is historisch gezien het analyseren van de socio-culturele context om zo vooruitgang te creëren in de vorm van positieve ervaringen in het dagelijkse leven (Beirne, 2011). Product ontwerpers kunnen hier aan bijdragen door producten te creëren met een goede product kwaliteitservaring. Om deze positieve product-kwaliteitservaringen te kunnen creëren moet de ontwerper kunnen anticiperen op de behoeften, eisen en wensen van de gebruikers. Deze behoeften, eisen en wensen veranderen continue. Er zijn velerlei tools, methoden, methodologieën, etc. om positieve ervaringen met producten te creëren zoals bijvoorbeeld: usability studies (o.a. Dumas, 2007), toepassen van ergonomische principes (o.a. Dul et al., 2012; Lee, 2006), participatief ontwerpen (o.a. Luck, 2003) of bijvoorbeeld human-centred design toepassen (Vink et al., 2008). Gezien deze brede waaier aan tools, methoden, methodologieën die beschikbaar zijn voor ontwerpers zou men verwachten dat de meeste producten op de markt gebruiksvriendelijk zijn en voldoen aan de verwachtingen, behoeftes en wensen van de gebruiker. Helaas is dit vaak niet het geval (Norman, 2010, Den Ouden, 2006; Norman, 2010; Nielsen, 2012; Van Kuijk, 2009). Het doel van dit onderzoek was te achterhalen of design onderwijs een effect kan hebben op de ervaren product kwaliteit. Om deze vraag te kunnen beantwoorden is de relatie onderzocht tussen de toegepaste activiteiten, methoden en tools in het ontwerpproces en de ervaren productkwaliteit. Deze activiteiten, methoden en tools worden in dit proefschrift samengevat in de term 'componenten in het ontwerpproces'. Dit onderzoek beperkt zich tot functionele fysieke producten en ontwerpprocessen van studenten van een specifieke opleiding, dus het veralgemenen van de resultaten moet met de nodige voorzichtigheid te gebeuren.

De hoofdvraag van dit doctoraatsonderzoek was "Welke componenten in het design proces hebben een positief effect op de ervaren productkwaliteit?" hierbij zijn er vier sub-vragen geformuleerd:

1) Welke componenten kunnen worden onderscheiden in het ontwerpproces?
2) Hoe correleren de componenten in het ontwerpproces met de ervaren product kwaliteit?
3) Zijn er verschillen in de ontwerpprocessen van design studenten en professionele ontwerpers?
4) Zijn design docenten in staat om de productervaring van gebruikers in te schatten?

(1) Om deze vraag te kunnen beantwoorden zijn eerst de componenten in het ontwerpproces geanalyseerd en gecategoriseerd en is de toepassingsfrequentie van deze componenten bestudeerd. Als men kijkt naar de toepassingsfrequentie worden 'ergonomische en functionele studies' over het algemeen het meest toegepast en het 'betrekken van gebruikers' worden het minst toegepast in de ontwerpprocessen van studenten.

(2) Vervolgens is er nagegaan wat het effect van de componenten in het ontwerpproces op de ervaren productkwaliteit is. Eerst in een casus met ontwerpen voor mensen met specifieke behoeften en/of beperkingen (vb. gehospitaliseerde kinderen) uitgevoerd en vervolgens zijn de ontwerpprocessen van een bredere groep van producten (o.a. Zit elementen, fietshulpstuk, etc.) bestudeerd. De conclusies van deze studies waren dat: in de studie met het herontwerpen van een bredere groep van producten blijkt dat het uitvoeren van een 'functie-en taakanalyse een risico- en fouten-analyse van het ontworpen product' een positieve correlatie met ervaren productkwaliteit. Bij het ontwerpen van volledig nieuwe producten heeft 'het betrekken van gebruikers in het ontwerpproces' een positief effect op de ervaren productkwaliteit, het gebruik van ergonomische richtlijnen daarentegen had een negatief effect. In de casus met de ontwerpen voor personen met specifieke behoeftes heeft 'ontwerpen door middel van het maken van (werkende) modellen', het uitvoeren van een 'functie-en taakanalyse een risico- en fouten-analyse' en 'gebruikers feed back over (werkende) concepten en modellen' een positief effect op de ervaren productkwaliteit.

(3) Daarnaast is er onderzocht of er gelijkenissen zijn in de design processen van studenten en professionele ontwerpers. Uit die studie blijkt dat professionele ontwerpers de gebruikers meer bevragen over het product en de gebruikers meer betrekken voor feedback over werkende prototypes dan de ontwerpstudenten. Meer ervaren ontwerpers doen meer ergonomische en functionele studies en betrekken meer gebruikers in hun ontwerpproces dan hun minder ervaren collega's.

(4) Als laatste is er gekeken of ontwerpdocenten in staat zij om in te schatten hoe gebruikers de productkwaliteit ervaren. Hieruit blijkt dat ontwerpdocenten goed kunnen inschatten hoe gebruikers producten ervaren indien het om producten gaat die bedoeld zijn voor het merendeel van de bevolking. Als het gaat om producten die ontwerpen zijn voor mensen met een beperking en/of zeer specifieke behoefte dan zijn docenten daar niet toe in staat.

Uit dit onderzoek zijn volgende conclusies te trekken: de ervaren productkwaliteit kan beïnvloed worden door de componenten in het design proces. De matige correlaties suggereren dat er nog andere factoren, naast de com-

ponenten in het ontwerpproces een invloed hebben op de ervaren productkwaliteit. Door de componenten die een positief effect hebben op de ervaren productkwaliteit, in het design onderwijs(meer) aandacht te geven kan design het ontwerp onderwijs een effect hebben op de ervaren productkwaliteit. Om ontwerp studenten op te leiden tot ontwerpers die in staat zijn om producten te creëren met een goede ervaren productkwaliteit is het nodig dat er in het onderwijsprogramma de nadruk gelegd wordt op componenten in het ontwerpproces die een positief effect hebben op de ervaren productkwaliteit. Zoals sommige componenten van de categorieën 'ergonomische en functionele studie', 'betrekken van gebruikers' en 'design onderzoeksmethoden'. Daarnaast is het ook belangrijk dat in design onderwijs gebruikers worden betrokken in het ontwerpproces van de ontwerpstudent(e) en in de evaluaties van de ontworpen producten.

References

BEIRNE, P., (2011), From Object to Objective: Reframing the Goals of Product Design Education in a Postindustrial Context. *IJ Design Principles and Practices*, Vol.5, Issue 6, ISSN 1833-1874.

DUL, J., BRUDER, R., BUCKL, P., CARAYON, P., FALZON, P., MARRAS, W.S., WILSON, J.R., AND DOELEN, B., VAN DER, (2012), A strategy for human factors/ergonomics: developing the discipline and profession. *Ergonomics*, 1–27.

DUMAS, J. (2007), The great leap forward: The birth of the usability profession (1988-1993), *Journal of usability studies* Vol. 2, Issue 2, USA, February 2007, pp. 54-60.

KUIJK, VAN, J.I., PREIJDE, E.E. , TOET, E.N., AND KANIS, H. (2009), Expected versus experienced usability: what you see is not always what you get. *IEA 2009: the 17th world congress on ergonomics*, August 9-14, Beijing, China, IEA.

LEE, L. (2006), *Learning Spaces: Human-Centered Design: Guidelines*. Educause, 2006.

LUCK R., (2003), 'Dialogue in participatory design', *Design Studies*, UK., November, pp 523-535.

NIELSEN, J. (2012), Usability 101: introduction in usability. *Alertbox*, ,from www. useit.com, January 4, 2012.

NORMAN, D. (2010), The Research-Practice Gap, Essays & Technology first, needs last: the research-product gulf. interactions, 17(2), 38-42, http://www.jnd.org/dn.mss/technology_first_needs_last.html, 2010.

OUDEN, E., DEN, (2006), *Development of a design analysis model for consumer complaints: revealing a new class of quality failure*. PhD Thesis, TU Eindhoven, NL.

VINK P., IMADA A.S., AND ZINK K.J., (2008), Defining stakeholder involvement in participatory design processes, *Applied Ergonomics* 39, USA, pp 519–526.

About the author

About the author

After her bachelor in Occupational Therapy, Barbara Kok completed a specialisation in Ergonomics. In 2004 she started teaching Occupational Therapy in the Health Care department at the PXL University College, (Hasselt, Belgium) where she was a researcher in several projects concerning occupational therapy and Multiple Sclerosis. She combined her job as occupational therapist with a study Master of Science in the Management and Policy in Health Care (VUB Brussels, Belgium) and graduated in 2005. In 2006 she started as lector in Product Ergonomics and researcher at Media Art and Design faculty,(MAD-fac), (Catholic University College Limburg, Genk, Belgium). At MAD-fac she was a researcher participated in research projects such as for example Mobile Design Lab, (http://www.socialspaces.be/projects/current-projects/mobiel-design-lab) and was the co-researcher in a TETRA project focusing on the technology transfer between education and companies. This 3 year project was about charging zones for electric vehicles including bicycles, motorcycles, and cars in which she led the design part of the project (http://laadzones.khlim.be/). As lecturer in the Product Design education she was also actively involved in reforming the curriculum of the Master in Product Design. In 2015 MAD-fac was integrated in the LUCA School of Arts. Currently Barbara works at the LUCA School of Arts, (MAD-fac) as a lecturer in Product Design and as a researcher in the Social Spaces (www.socialspases.be) research group, a part of the research unit Inter-actions of the LUCA – faculty of the Arts (Belgium) (www.socialspaces.be).

Publications

Publications

KOK, B.N.E., SLEGERS, K., AND VINK, P. (2010), Tools for more user friendly design: do they really improve the quality of the design? *Cumulus Congress Genk*, Belgium.

KOK, B.N.E., K. SLEGERS, AND P.VINK, (2011) Methods of the design process: an inventory. ODAM 10th symposium, Grahamstown, South Africa.

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2012) The amount of ergonomics and user involvement in 151 design processes. *Work 41: 989-996*

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2013) The effect of the designers approach on the user experience: an exploratory case study. *Cumulus conference Design in Times of Austerity* United Kingdom. (Accepted conference paper)

KOK, B., SLEGERS, K., AND VINK, P., (2014) Can design teachers evaluate students' products from an end-user point-of-view? In: *Advances in Social and Organizational Factors 2014*, Ed. P Vink, Published by AHFE Conference © 2014, page 59-67.

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2015), The effect of the designer's approach on the perceived product quality: an exploratory case study of tangible products. *The value of Design Research. European conference of design conference*, Paris, France.

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2016), : Components in the Design Process Essential for Ergonomic Sound Products. *Ergonomics in Design.* (accepted 2015)

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2015), Essentials in the Design Process for Creating Comfort in vehicle Seats. Applied Ergonomics. (submitted 2015)

KOK, B.N.E., SLEGERS, K., AND VINK, P., (2016), Are seat design processes of students similar to those of professionals? . *Work 41: 989-996*

Acknowledgements

Acknowledgements

I would not have been able to do this PhD without the help and support of many people. I would like to thank all the people who have supported me in one way or the other.

A special thanks goes to Peter and Karin my promoter and co-promoter, without their support and feedback this PhD would not have existed. I would like to thank my family for their support especially my husband, Benjamin and my two lovely daughters Yasmina and Emma, and my mother. Also my fellow PhD students were also very important to me: thank you for your support, the interesting feedback and the research discussions we had on several occasions; thank you Conne and Nancy for reviewing my English and your mental support. Thank you my colleagues were also very supportive. A special thanks goes to my students not only for providing me with the data by patiently filling in the questionnaires, but also for their interest and support. I would like to thank all the users and professional designers and teachers who participated in the studies. For the and illustrations I would like to thank my brother Sebastiaan, Michiel for the lay-out and Kris for creating the online survey. A special thank goes to my Paranymfes Ilse and Sebastiaan for their support. I would like to thank the LUCA School of Arts, MAD-faculty and the TU Delft for giving me the opportunity to do this PhD research. And last but not least I would like to thank all my friends and family for their support. To all those I forgot to mention: I am very sorry and thank you anyway!

All of you thank you for enduring all my complaining for forgiving me for my lack of time for you, thank you for supporting me and baring my chaotic way of thinking, and thank you for enduring my mood swings. I promise from now on I will … probably stay the same :-).

Barbara